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February 2005
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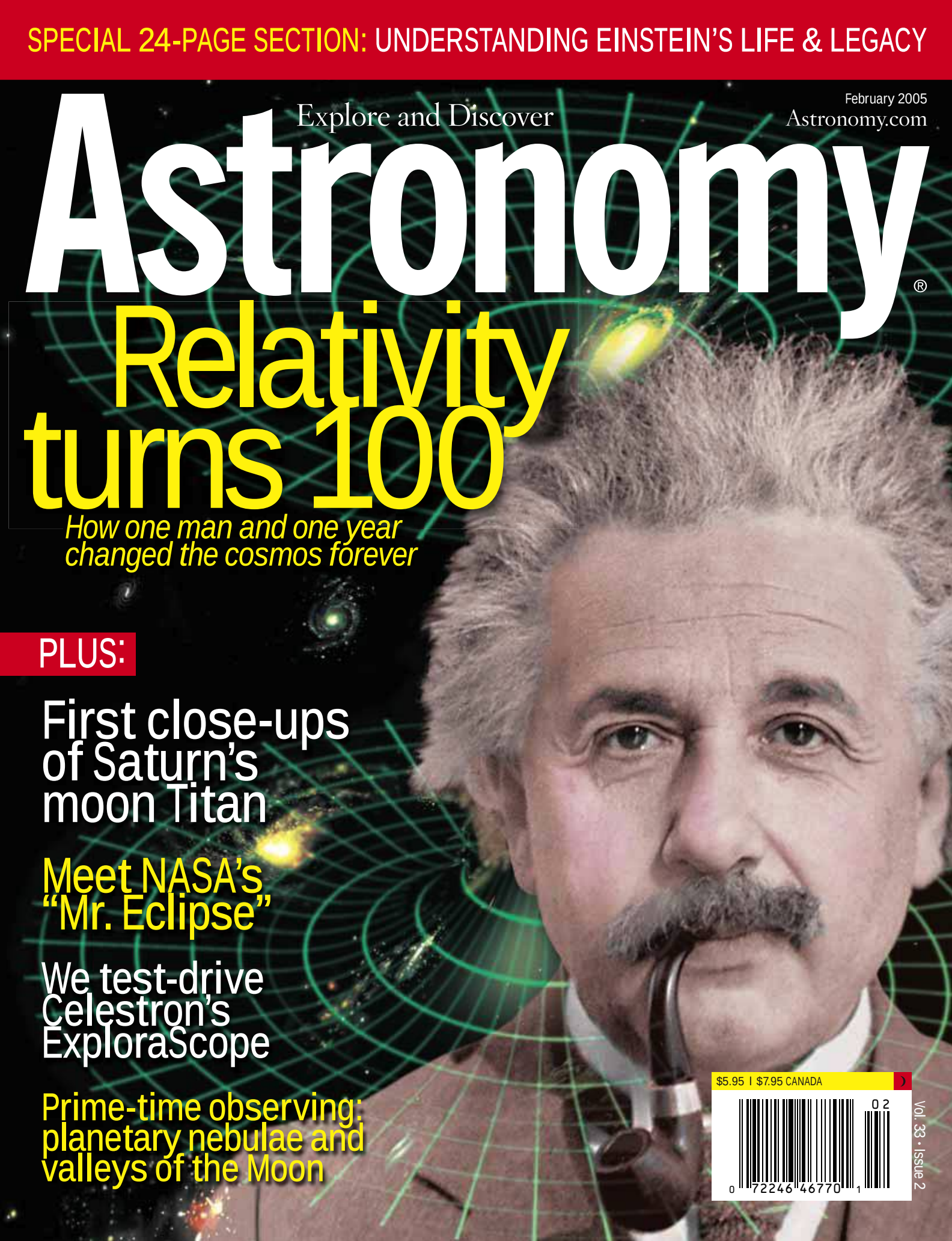

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Vol. 33 • Issue 2

Redefining the Eyepiece

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Series 5000™

Ultra-Premium Eyepieces

TeleXtenders Series 5000

The new Series 5000 TeleXtenders are the finest power multipliers sold today. Their advanced 4-element design delivers a flatter field-of-view with sharper edges than even the best 3-element apochromatic barlows. They feature fully multi-coated lenses with no color fringing. Get all of the benefits from your 2" eyepieces with the new Series 5000 2x 2" TeleXtender (with 1.25" adapter). The 5x TeleXtender is a perfect match for short focal length refractors — particularly for viewing or imaging planets in minute detail.

- Flat field-of-view
- Premium grade optical glass
- Individually tuned, multi-layered coatings for maximum light transmission and highest contrast
- Lens edges and all internal metal surfaces are blackened to maximize image contrast
- Maintain the comfortable eye relief of longer focal length eyepieces while increasing the magnification

Magnification	Barrel Size	# of Elements	Price
2x	1.25"	4	$ 159.00
3x	1.25"	4	$ 159.00
5x	1.25"	4	$ 159.00
2x	2.00"	4	$ 229.00

5 Element Plössl Series 5000

The new Series 5000 Plössl eyepieces represent a milestone in design and engineering. The five and six element designs feature tack sharp optical performance which delivers a 40% improvement in corrections for chromatic aberration and edge-distortions over traditional plössls. They yield the widest possible fields-of-view, consistent with pinpoint edge-of-field sharpness and contrast. Compare their unparalleled 60˚ apparent field-of-view to any Plössl on the market today. Take a look through the new Meade Series 5000 Plössls and rediscover your favorite celestial objects.

- Wide 60˚ apparent field-of-view
- Premium grade optical glass
- Individually tuned, multi-layered coatings for maximum light transmission
- Lens edges and all internal metal surfaces are blackened to maximize image contrast
- Parfocal - little or no refocusing required when switching eyepieces
- Long eye relief
- Adjustable twist-up rubber eyeguards

Focal Length	Barrel Size	Apparent FOV	# of Elements	Price
5.5	1.25"	60˚	6	$ 89.00
9	1.25"	60˚	5	$ 89.00
14	1.25"	60˚	5	$ 89.00
20	1.25"	60˚	5	$ 89.00
26	1.25"	60˚	5	$ 99.00
32	2.00"	60˚	5	$149.00
40	2.00"	60˚	5	$199.00

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Never before has the serious astronomer been able to purchase premium eyepieces of this quality with these features at these prices.

Super Wide Angle Series 5000

The new Series 5000 Super Wide Angle eyepieces boast a 68˚ apparent field-of-view and image resolution that is razor sharp from edge-to-edge. Because of its innovative six element design the objects you observe will be rich in detail and contrast with virtually no chromatic aberration. These eyepieces are made of the finest materials available, and are a perfect optical match for Schmidt-Cassegrains, fast Newtonians and Schmidt-Newtonians. First light with the new Series 5000 Super Wide Angle eyepieces will be an event you'll always remember.

- Super Wide 68˚ apparent field-of-view
- Premium grade optical glass
- Individually tuned, multi-layered coatings for maximum light transmission
- Lens edges and all internal metal surfaces are blackened to maximize image contrast
- Parfocal - little or no refocusing required when switching eyepieces
- Long eye relief
- Adjustable twist-up rubber eyeguards

Focal Length	Barrel Size	Apparent FOV	# of Elements	Price
16	1.25"	68˚	6	$179.00
20	1.25"	68˚	6	$199.00
24	1.25"	68˚	6	$249.00
28	2.00"	68˚	6	$279.00
34	2.00"	68˚	6	$299.00
40	2.00"	68˚	6	$399.00

Ultra Wide Angle Series 5000

Representing the ultimate in eyepiece design and technology, the new six and seven element Series 5000 Ultra Wide Angle eyepieces deliver extremely high resolution, contrast and full-field sharpness over an astounding 82˚ apparent field-of-view. Only the highest quality materials were selected to create these extraordinary eyepieces. The designs required several different types of exotic glass in order to achieve the highest level of optical performance. Looking through a Series 5000 Ultra Wide Angle eyepiece is the next best thing to actually being there.

- Ultra Wide 82˚ apparent field-of-view
- Premium grade optical glass
- Individually tuned, multi-layered coatings for maximum light transmission
- Lens edges and all internal metal surfaces are blackened to maximize image contrast
- Parfocal - little or no refocusing required when switching eyepieces
- Long eye relief
- Adjustable twist-up rubber eyeguards

Focal Length	Barrel Size	Apparent FOV	# of Elements	Price
4.7	1.25"	82˚	7	$199.00
6.7	1.25"	82˚	7	$199.00
8.8	1.25"	82˚	7	$199.00
14	1.25"	82˚	7	$199.00
18	1.25"	82˚	6	$279.00
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30	2.00"	82˚	6	$449.00

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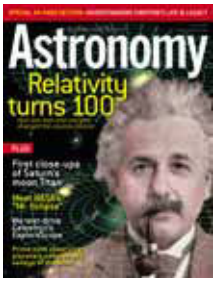

ON THE COVER
A century ago, Swiss patent examiner Albert Einstein turned physics upside down with a handful of papers compelling physicists to look at the universe differently. Find out what he did — and how he did it — in 24 pages of special coverage starting on page 30.
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THE MAN WHO REMADE THE UNIVERSE: Listen to Einstein discuss his famous equation, $E=mc^2$.

RELATIVITY'S INFINITE BEAUTY: Join the search for gravity waves, an effect Einstein predicted.

CASSINI TARGETS TITAN: See the latest images returned from Saturn's mysterious moon.

SEE A STAR DIE: Check out planetary-nebula images captured by the Hubble Space Telescope.

MEET "MR. ECLIPSE": Find out what makes a great eclipse as Fred Espenak shares his favorites.

LETTERS: Article author Robert Zimmerman and astronomer Alex Filippenko exchange views about "The looming death of Hubble" (November 2004).

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BY DAVID J. EICHER

Remembering Einstein

One hundred years ago, the cosmos

changed forever. In his *annus mirabilis*, or miracle year, Albert Einstein single-handedly revolutionized physics. At age 26, the Swiss patent clerk introduced to the world the special theory of relativity, in which he showed that space and time cannot be separated. Suddenly, although not everyone realized it at first, the bedrock on which physics existed — the absolute, mechanical concepts of Sir Isaac Newton — was bounced on its head.

Einstein's scientific productivity in 1905 is simply astonishing. In March, he submitted for publication a paper arguing that light waves behave as if they are also particles. This radical notion explained the photoelectric effect, which had been observed experimentally. It also explained the quantum theory of energy that Max Planck had proposed (and only half believed in himself) 5 years earlier. Built upon by Niels Bohr and, later, Planck, Einstein's path-breaking concept showed we live in a quantum universe.

During the next few months, Einstein continued to write at a furious pace. In May, he completed a paper explaining Brownian motion. It showed atoms definitely exist — although not all physicists agreed — and heat comes from molecular motion. He then conceived the idea of special relativity and wrote it up by late June.

As if that weren't enough, in August, he sent off his doctoral dissertation on the size of molecules; with small revisions, it was accepted. In September, Einstein revisited the theory of special relativity and extended its conclusions, linking matter to energy. These ideas converged in the famous equation now written as $E=mc^2$.

Thus, in a single year, Albert Einstein sent human understanding of the cosmos into a completely new dimension.

This month's *Astronomy* is a special issue devoted to Einstein's miracle year and his subsequent contributions to our knowledge of the heavens.

In our lead story, "Relativity turns 100," veteran science journalist Richard Panek offers an insightful analysis of how Einstein did what he did (page 32). Senior editor Robert Burnham follows this with "The man who remade the universe," a photographic essay describing the scientist's life and adorned with 32 photos of the great man, including many rare images from archival collections (page 38).

Finally, physicist James Trefil of George Mason University describes "Relativity's infinite beauty" in a story that carries forward from the miracle year and highlights what arose from Einstein's general theory of relativity, published in 1916 (page 46).

I know you will greatly enjoy this look at Einstein's giant contributions to understanding the cosmos. Astronomy would be a mere shadow of itself without this genius, the man who redefined how we see stars, galaxies, and ourselves. I invite you to let us know what you think about this special package honoring Albert Einstein.

Yours truly,

David J. Eicher
Editor

Astronomy

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"The LX90 performed beautifully on splitting colorful and close double stars.... Antares is easy to split in an 8-inch. What makes it difficult to resolve sometimes is not the separation (3"), but the difference in brightness between the 1st-magnitude primary and its 7th magnitude companion. The LX90 split it with ease and revealed the duo's nice orange-blue color contrast as well.... The optics in the LX90 were defect-free." ***– Astronomy Magazine***

POINTING & TRACKING ACCURACY

"The altazimuth tracking was excellent. One evening I centered the Whirlpool Galaxy, M51, in the eyepiece and let the scope track unattended as the galaxy rose in the northeast and passed near the zenith. After more than four hours it was still dead-center in the field.... The computer pointing is also remarkably accurate." ***– Sky & Telescope Magazine***

AUTOSTAR

"They make it easy for beginners to explore the sky and grant experienced observers more time looking at objects than hunting them.... Having AutoStar at my fingertips easily tripled the number of targets I viewed in the space of a few hours. A key feature for experienced observers, you can observe more targets in a given time." ***– Astronomy Magazine***

ASTROPHOTOGRAPHY

"With a strong background in astrophotography, I was particularly interested to see if the LX90 would live up to its claims. The short answer? It certainly does, and then some." ***– Sky & Telescope Magazine***

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•Type 5: 31, 26mm for wider true fields, 20, 16mm lighter and smaller than Type 4.

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Radian 60°

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Plössl 50°

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Nagler Zooms 50°

High power planetary eyepieces with a whole new "twist." Tune the magnification to the highest your sky conditions allow.

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Plössl Eyepieces - Magnify to Taste.

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While top-rated Tele Vue Barlows mate well with all eyepiece types, Barlows (and short ones in particular) diverge light, which can cause vignetting in some eyepieces. To minimize this effect, we created "Powermate," which integrates a "field lens" to redirect light rays to their original direction. Also ideal for imaging.

Bino Vue

Your brain likes what it sees using two eyes! The field appears larger with an added 3-dimensional effect to deep sky objects, planets and the Moon. Nagler designed correctors compensate for naturally occurring prism aberrations and will not vignette even the largest field (24mm Panoptic), or affect your scope's high power performance.

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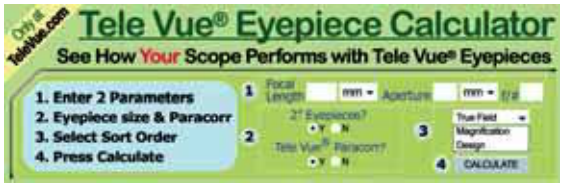

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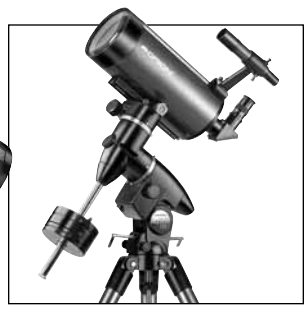
SVP 80 ED & FREE drive **$839**

SkyView Pro 8 EQ
A full 8" (203mm, f/4.9) parabolic primary mirror, which gathers 73% more light than a 6". The tube features a 2" aluminum rack-and-pinion focuser and a sturdy 4-vane holder. Includes 6x30 finder scope, two 1.25" Sirius Plössl eyepieces (25mm and 10mm), collimation cap and dust-cap.

SVP 8 & FREE drive **$549**



SkyView Pro 127 EQ
The 5" Maksutov-Cassegrain optics offer great views of deep-sky gems. And its long focal length of 1540mm (f/12.1) is great for high-magnification study of the Moon and planets. Includes 6x30 finder scope, two 1.25" Sirius Plössl eyepieces, 90° mirror star diagonal, optical tube carry case and dust-cap.

SVP 127 EQ & FREE drive **$649**

New! & Notable

Waist Case™ Accessory Holder

Keeps your most-often used accessories right at your fingertips. Foam interior has seven die-cut holes for 1.25" and 2" eyepieces. Front and side pockets hold filters and other accessories. Belt adjusts to most waist sizes.

$32.95

SkyLine™ Green Laser Pointer

Point right to the Orion Nebula, or trace the outline of the Sagittarius "Teapot." SkyLine's thin but distinct green beam appears to stretch all the way to the stars! A great teaching aid for night-sky viewers. Two AAA batteries and case included.

$129

Focus Wheels, Radial Aluminum

Give your scope a high-end makeover. Replace those black plastic focus knobs with these eye-catching, machined aluminum mags. They fit most Orion telescopes and many other scopes. Set of two wheels with mounting screws.

$24.95

Deluxe Case for ED80 Refractor

Custom designed for the Orion 80mm ED refractor. Has wood panels with black, water-resistant PVC exterior and reinforced aluminum edges. Die-cut foam interior holds scope plus 30mm finder, 2" diagonal, and three 1.25" eyepieces.

$89.00

Astronomer's VersaTool™

The first multi-tool designed for astronomers. Contains 21 different tools (we think, we lost count!), including optics brush, red LED flashlight, wrenches, hex keys, pen, knife, and bottle opener for that bubbly beverage! Comes with belt case.

$24.95

Eyepieces

Ultrascopic™ Eyepieces

Upgrade from Plössls for better images. Fully multi-coated, Japanese-made optics deliver flat-field images of exceptional resolution. Each comes with detachable winged rubber eyeguard. The 1.25"-diameter barrels are threaded for filters.

From **$89**

HighLight™ Plössl Eyepieces

Our premium line of Plössls provide that extra performance edge. Optics are fully multi-coated for highest possible brightness and contrast. Unique knurled-metal grip. Generous 52° apparent field (40mm, 43°). The 1.25"-diameter barrels are threaded for filters.

From **$54.95**

Sirius™ Plössl Eyepieces

Enjoy excellent image sharpness and contrast for a great price. Fully coated, 4-element optics offer a 52° apparent field (40mm, 43°). Ideal for all types of telescopes. The 1.25"-diameter barrels are threaded for filters.

From **$42.95**

Electronic Imaging Eyepieces

View real-time images of the Moon, planets, or terrestrial subjects on a TV, or record on a VCR for later playback or frame-grabbing. Monochrome and color models fit any 1.25" focuser or diagonal. Cable and 9V battery included.

Monochrome **$64.95**
Color **$119**

Filters

Full-Aperture Solar Filters

View the Sun safely, in natural color. Enjoy great views of sunspots! Triple-coated glass blocks 99.999% of incoming light. Aluminum cell. Sizes to fit telescopes apertures from 3.5" to 12". See complete list at telescope.com.

From **$54.95**

Moon Filters

Neutral-density filter reduce lunar surface glare to reveal much more detail. Works with any telescope and at any Moon phase. Antireflection coatings prevent ghosting. Anodized aluminum cells.

1.25" 13% Transmission **$14.95**
1.25" 25% Transmission **$14.95**
2" 13% Transmission **$19.95**

SkyGlow™ Broadband Filters

Blocks the most common wavelengths of light pollution, enhancing contrast on all deep-sky objects, especially emission nebulas. Great for viewing in areas of moderate light pollution.

1.25" **$59.95** *2"* **$74.95** *SCT* **$79.95**

UltraBlock™ Narrowband Light Pollution Filters

A must for observing in areas of heavy light pollution, or for maximum contrast enhancement on emission nebulas. Anodized aluminum cells.

1.25" **$79.95** *2"* **$99.95** *SCT* **$110**

Deluxe Stargazer's Filter Set

For the observing enthusiast, this six-filter collection is all you need. Includes SkyGlow, variable polarizing filter, and four color planetary filters (1.25") in one carry-all case.

$114.95

Stargazer's Filter Set

Save on these four essential filters, complete with foam-lined protective case. Includes SkyGlow, Moon filter, #25 red and #80A medium blue color filters. For beginning to advanced stargazers.

1.25" **$79.95** *2"* **$119.95**

Observing Aids

Orion LaserMate™ Deluxe Collimator

For precise collimation of your reflector's optics. The LaserMate Deluxe turns collimation into a one-step process by adding a "rear view" port so you can see both the emitted and return beams while standing at the rear of the telescope. Both fit any 1.25" eyepiece holder.

$79.95

SteadyPix™ Universal Camera Mount

Take awesome through-the-eyepiece shots of planets, the Moon, or terrestrial subjects with your digital or film camera. SteadyPix couples camera to most 1.25" telescope eyepieces.

$34.95

Dynamo™ 12V DC Power Station

Portable power for your 12-volt telescope drive and electronic accessories. It has 7 amp-hour capacity, two DC ports, and built-in red flashlight. Fully rechargeable with included AC adapter.

$56.95

Explorer™ Astro Binoculars

New!

With our jumbo Explorer binoculars, you'll see the night sky like never before. Large-aperture, fully multi-coated BAK-4 optics provide exceptional light gathering for vivid images. The barrels are cross-reinforced for structural rigidity. Sliding 1/4"-20 mounting post couples binocular to a tripod. Includes foam-lined aluminum case.

25x100 Explorer $329
20x80 Explorer $279

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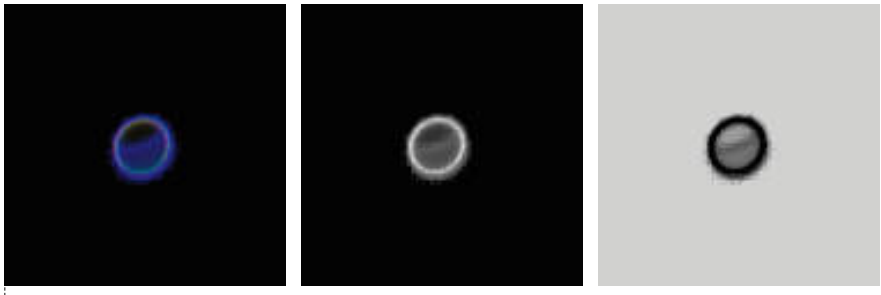
Blue-light special

When film was primarily used for astronomical imaging, photos of the remote gas giant Uranus usually showed nothing more than a speck. When the image was done well, we could see some of Uranus' bright moons. « Due to the long exposure times needed on film, it was nearly impossible to get good images of Uranus' disk, which is small and dim through every telescope.



THIS COMPOSITE IMAGE, shot through a blue filter, shows Uranus' south polar region as a dark spot on the blue and black-and-white images (left and center) and a light spot on the negative image. RALF VANDEBERGH

Nowadays, thanks to CCD-camera technology, Uranus is becoming a better target for amateur astronomers to photograph. Uranus will become more interesting as we approach its spring equinox in 2007.

The most prominent feature of Uranus now is the south polar region, which is visible clearly in red and infrared light. Thanks to planetary scientist Heidi Hammel, however, I learned the feature becomes dark when it's imaged through a blue filter.

My observation (above) from October 2, 2004, shows this effect clearly. I took this image with a 10-inch Newtonian reflector and an ATIK instruments ATK-2C air-cooled CCD camera. The result is an average of 90 exposures of 0.5 second using a resolution of 0.25" per pixel.

— RALF VANDEBERGH, WITTEM, NETHERLANDS

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

The future of space telescopes

I enjoyed Ray Villard's "Beyond Hubble" (October 2004) but am aghast at the tautology of NASA's phrase "Lunar Gateway Portal." A gateway *is* a portal.

NASA needs to call the L1 staging point something that does not sound like a term invented by a bureaucrat and also reflects its new solar-system-wide theater of operations. How about "Earth Depot"?

— GEORGE STACEY, CALGARY, ALBERTA

Correction

On page 90 of the January issue, we mistakenly pictured the Denkmeier binocular viewer instead of the Denkmeier 2" SCT diagonal. Look for correct descriptions of both products in an upcoming issue. — *ASTRONOMY* EDITORS

Experts sound off about Hubble's fate at www.astronomy.com/toc

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Moving up to a Digital SLR camera?

The MaxView-DSLR is for you!

DSLR II shown on a Canon 10D*

Finally a variable projection adapter large enough to hold ANY eyepiece! Now you can use your best eyepieces for astrophotography. The picture at right shows the 1.25" version (left), the 2" version (right) and a standard sized projection adapter between them for scale. The 1.25" version will accept any 1.25" eyepiece. The 2" version will accept any 1.25" or 2" eyepiece...yes even a 31mm Nagler! Both versions include a removable MaxPower lens to increase magnification and allow use in scopes with very little back focus. These are variable length adapters allowing you to adjust the magnification in small increments to fill the frame. Change eyepieces in seconds. Machined from solid aluminum, anodized black with a knurled grip ring. 2" version includes 1.25" adapter. Both units are T threaded for use with standard T-Rings. Can be used with 35mm SLR cameras too! *Camera not included.

1.25" MaxView-DSLR **2.00"**

1.25" *MaxView-DSLR* (STSLR1) $129.00 | 2" *MaxView-DSLR* (STSLR2) $189.00

MaxView™ & MaxPower™ Lenses
S&T Hot Product 2003!

Our award winning MaxView 40 and new MaxView II Digital Camera Adapters are specially designed eyepieces for use with digital cameras. Designed to give the least vignetting, even when used with large lensed cameras. The MaxView 40 is 1.25" format while the MaxView II is 2" format. We carry dozens of adapter kits to fit either MaxView to most all digital cameras with threaded lenses. Our new MaxPower™ lenses thread into the bottom of the MaxView eyepieces to increase magnification by 60% while maintaining the desirable properties of the MaxView eyepieces. We also have versions made specifically for use with Microscopes and most popular nature scopes such as Swarovski, Pentax, Leica, Zeiss and more! **Patent Pending.**

1.25" MaxView $129.95

*Mounted on Sony 717
2" MaxView II $189.95

Awarded "Hot Product" SKY™ & Telescope Magazine 2003

MaxPower 1™ 1.25" 39.00
MaxPower 2™ 2.0" 69.00

The Digi-T™ System

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Fits: Meade Super Plossls, Celestron NexStar Plossls, ScopeTronix ST Series, Orion Sirius Plossls, and many more eyepieces with removable rubber eyeguards.

GPS for your Autostar!

Easy to install unit adds GPS functionality to many scopes. Versions to work with Meade ETX, LX90, LX200 (GPS and Classic), No more entering the time, date, and location! It is all entered for you at very high accuracy! See our website for full details and model number for your particular telescope.

STARGPS $199.00

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All adapters fit 1.25" focusers

We carry adapters to attach most popular webcams and "C" mount security cameras to your telescope. See our website for your specific camera models.

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STWCA2 Fits QuickCam, 3com and more **29.95**
STWCA3 Fits Vestra Pro, Kensington, more.... **29.95**
STC125 Fits all "C" Mount cameras..... **22.95**

MaxView Digital Camera Adapter for Nikon 950/990/995/4500

These wide field (66 Degree) eyepieces can be used visually or threaded directly to Nikon cameras with a 28mm thread. The ONLY vignette free adapter for the cameras listed above on the market!

STWA14 14mm... 109.00 | STWA18 18mm... 99.00

The ScopeTronix EZ-PIX™ Universal Digital Camera Adapter

No lens thread on your digital camera? No problem! Our universal design fits any camera with a standard 1/4-20 threaded mounting hole. The padded eyepiece clamp slips over most Plössl eyepieces and barlow lens. The EZ-PIX is the original universal camera adapter, don't be fooled be cheap imitations that claim to be of an improved design. *The EZ-PIX is still the best design available!* Spacer included (shown at right)
Now includes two padded clamps to fit a wide variety of eyepieces!
STEZPIX Universal Digital Camera Adapter..... **49.95**

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The ScopeTronix Multi-Mate is four handy devices in one compact inexpensive unit. Great for GOTO scope setup. Insert it into your eyepiece holder and use the bubble level to quickly and accurately level your optical tube. Flip it over and use the handy compass to quickly find North. When your scope is in storage it acts as a dust plug and in addition it contains a replaceable bag of desiccant to protect your scope in storage. The desiccant draws moisture out of your OTA through small holes around the compass and traps it in the desiccant chamber. This helps prevent optical damage due to moisture and mold formation. **STMM** 4 in 1 Multi-Mate... **$24.95**

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Monoculars convert to a telephoto lens for digital cameras. Available in two sizes to fit most digital cameras.

CVOSS (28/37mm Cameras)..... **149.00**
CVLX (T-Threaded Adaptable)..... **189.00**

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Custom machined black aluminum filter cell securely threads onto telescope.

STSF60 fits ETX60 and ETX70..... **64.95**
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STSF105 fits ETX 105..... **94.95**
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STPL15 15mm ST Series Plössl **37.95**
STPL20 20mm ST Series Plössl **37.95**
STPL25 25mm ST Series Plössl **37.95**
STPL32 32mm ST Series Plössl **42.95**
STPL40 40mm ST Series Plössl **42.95**
STPLSET Complete Set (9)..... **249.00**

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STBAR2 2x **39.95**
STBAR3 3x **42.95**
ST2BAR2 2x 2" **79.95**

Color Filter Set For 1.25" Eyepieces

STCFS...37.95

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STEPB4 Eyepiece Bottle - 2.0" ID, 3.2-4.7" Length **5.00**
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STPB90 ETX-90EC/RA....**49.95**
STPB125 ETX-125EC.....**64.95**
STPBN5 NexStar 5..... **59.95**

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Protect your Auto star from the dew and keep it working like new!

SASC 34.95

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Accessory Tray for ETX
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Replacement Eyeguard

Fits many common 1.25" eyepieces.
STEYEG 2.50

ScopeTronix Flexi-Focus™ for ETX Telescopes

Oversized knob and flexible shaft allow crisp, sharp focusing even when OTA is pointed straight up!

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Flexible shaft reduces vibrations Achieve sharp focus fast!

ScopeTronix Green Laser Pointer

5mw *continuous mode* laser beam is easily visible at night! 2 AAA batteries included.

STGREEN 5mw Green Laser Pointer **$189.00**

ScopeTronix Tripod Bag for LX Tripods

Our quality tripod bags are designed for the Meade field tripod used with the LX series scopes up to 10" such as the LX10/50/90/200/GPS. Features include full interior padding, heavy duty carry handles, an adjustable shoulder strap, color keyed to match the Meade soft case, and an outside pocket sized just right for a set of vibration suppression pads!

STBAGLX LX tripod bag **79.00**

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- **Heavy-duty tripod** with ultra-sturdy 2" stainless steel legs, center brace and accessory tray for superior stability, rigidity and vibration dampening
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Benefits of Advanced Series GoTo

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Auxiliary ports for Hand Control, Dec Motor and AutoGuider.

C11-SGT (#11067)

Advanced Features for Astrophotography

- **Programmed polar alignment** feature walks you through the steps of aligning the telescope to the Earth's axis which is required for astrophotography
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- **Precise GoTo** ensures that hard to find objects are centered in the field of view with higher accuracy

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- **GPS compatible** for even quicker and easier setup, Advanced GoTo models can also be upgraded to GPS scopes with the optional CN16 GPS Accessory Kit (#93966). Kit contains the CN16 GPS module, bracket and holder, and Auxiliary Port Expander
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For more information on Celestron's Advanced Series models, visit www.celestron.com.

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WHAT'S IN A NAME?

Here's a quick guide to identifying the various types of Celestron Advanced Series telescopes:

S = Schmidt-Cassegrain
N = Newtonian
R = Refractor
GT = Computerized GoTo

Example: C10-NGT
10" Newtonian on a computerized mount.

Item No.	Model	Price + S&H
11067	C11-SGT	$1,999 + 125
11066	C11-S	$1,699 + 105
11048	C10-NGT	$1,199 + $95
11047	C10-N	$909 + $75
11046	C9¼-SGT	$1,779 + $105
11045	C9¼-S	$1,469 + $85

Item No.	Model	Price + S&H
11026	C8-SGT	$1,359 + $95
11025	C8-S	$1,059 + $75
31062	C8-NGT	$1,019 + $85
31061	C8-N	$699 + $65
21020	C6-RGT	$1,069 + $95
21019	C6-R	$849 + $75

Item No.	Model	Price + S&H
31056	C6-N	$399 + $50
31053	C6-N HD	$529 + $50
31054	C6-NGT	$799 + $70
11072	C5-SGT	$1,099 + $75
11071	C5-S	$849 + $65
21016	C4-R	$399 + $40

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Image by Bill Dean H.O.T.S. 2004

Coronado would like to thank all of the attendees from H.O.T.S.™ 2004 for contributing to the success of our 4th annual Solar conference and workshop. While you have to wait a until Oct. 2005 for your chance to come experience the sun with us, you can get a jump start on observing the sun our way! With our complete telescope system's from $500.00 and filters for adapting your scope from $1099.00 you will be able to enjoy astronomy in ways you never thought possible by observing a working star. Watch features on our solar system's largest resident change on a minute by minute basis. Viewing, binoviewing, and imaging are all possible with Coronado's state of the art instruments. You can be assured of performance, safety, and quality from the leader in solar observing, Coronado.

Awarded 2004 Best of What's New by Popular Science magazine!

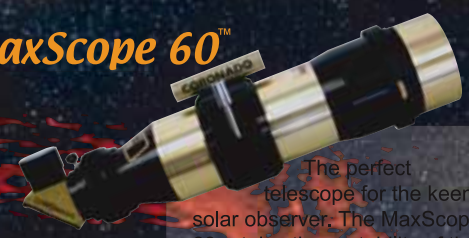
P.S.T™

The Personal Solar Telescope™ has received the 2004 Best of What's New award in the Aviation and Space category from Popular Science magazine. As did the Large Binocular Telescope featured in the H.O.T.S. group photo above...cost $110 million. P.S.T. $499. Ready to use out of the box this complete H-alpha telescope will delight even the most experienced observer.

MaxScope 40™

The original solar 'scope. From the beginning this telescope was designed to revolutionize H-alpha observing. The MaxScope 40 is light-weight and extremely portable at just under 3lbs! Don't let size fool you, this little scope gets some big images, just ask any of the thousands of owners worldwide!

MaxScope 60™



The perfect telescope for the keen solar observer. The MaxScope 60 retains the portability of the 40mm telescope with the advantage of a larger aperture. The 60mm aperture of the front mounted narrowband etalon allows for increased resolution and provides enhanced performance for both visual and photographic use.

For information on filters, dedicated Solar telescopes (40mm to 140mm), CEMAX eyepieces, white light accessories, and a full list of authorized dealers contact Coronado

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Solar Image By Jack Newton www.jacknewton.com

BY BOB BERMAN

Astrospeak

Every profession has its own language.

That's why the word "draw" means different things to poker players, cartoonists, and gunslingers. Astronomers are no different. The jargon can be baffling to a spouse who gets dragged to a star party and is subjected to hours of Dobs, Barlows, Messier numbers, and the rest. It's our own vernacular — astrospeak. Where else can one encounter a "clock drive"? An outsider couldn't begin to guess what that might be.

While much of astrospeak involves tech terms like CCD or focal length, some of it sounds like baby talk. White dwarf. Red Spot. Or seeing, as in "The *seeing's* so bad the rings are blurry." When a friend first heard that, he was amazed: "Astronomers speak of *seeing*? Not some technical term that rates the air's steadiness? You've got to be kidding. *Seeing*?"

I don't care, I like the word. "Seeing" says it flat out. Who cares if it makes us sound like 6-year-olds?

As long as we're thinking of names for things that don't have them, let's rename a bunch of stuff. For instance, it's not fair the features on the Moon's farside have Russian labels. And, have you ever tried to utter Libra's two brightest stars, Zubeneschamali and Zubenelgenubi? Forget it. Change them to Bill and Judy.

Also, let's do away with the sillier deep-space names. Dumbbell Nebula? Black Eye Galaxy? What joker decided to name star-birth places after gym equipment or injuries? Orion. Andromeda. Those are names. We'll keep a few funny ones like Betelgeuse just for laughs.

Replacement names? There are a few ways we can go with this:

1. Kids love constellations but have few they can handle. So call the new ones Muffy, Tabby, and Spot.

2. The sky is loaded with archaic job descriptions like Ophiuchus the Serpent-bearer. Nobody carries snakes for a living anymore, so add actual occupations like Phoebe the Flight Attendant.

3. Retire the outdated tools in the sky like Antlia the Air Pump and replace them with names like Debby the Dobsonian.

4. If we run out of patterns, we'll switch to the Chinese sky-scheme of countless teeny-weeny ones. Orion gets cut into several new constellations. His belt turns into a frankfurter. His little triangular head becomes an airline terminal's luggage area.

One problem is that the International Astronomical Union, the official organization that names things, is composed of the most staid and humorless people on Earth. Listen to how they insist NASA names the new objects the Cassini spacecraft is now finding on Saturn's moons:

"Titan's features are to be named for ancient displaced cultures. Iapetus' will be people and places from Sayer's translation of *Chanson de Roland*. Dione: People and places from Virgil's *Aeneid*. Mimas: People and places from Malory's *Le Morte D'Arthur* (Baines Translation)."

I'm not making this up. No characters from *The Simpsons*. Nothing whimsical at all. Touring the solar system will be like sitting through freshman English.

The cosmos is serious business, and we have to wipe those silly grins off our faces. Right? Yes sir, you can say that again.

{ Orion gets cut into several new constellations. His belt turns into a frankfurter. His little triangular head becomes an airline terminal's luggage area.

Rather than limiting our use of astrospeak, we should create more of it. Astrospeak has no term for staring into an overcast sky during a total eclipse. The thwarted observer's expression of disgust and disbelief deserves its own name, too. It's useful in many astro-situations, like when your friends cheer at a sudden fireball that you missed while searching for the most recently dropped eyepiece.

We also need a term for the act of repeatedly nudging a telescope, as when the drive isn't working or you polar aligned it to, say, Virgo. When else in life do you move an object at 1-minute intervals? You'd have to be insane.

I think our spacecraft also deserve better or less-risky appellations. Challenger? Bad name. Who or what were we challenging up there? It's like naming a rocket "Titanic" or "I dare you." Endeavor is nice, so is Discovery. Atlantis — that's iffy. Personally, I would feel more comfortable in a shuttle named "Please-don't-hurt-me." But that's just me.

Let's even rename some constellations. Half are fine. Maybe three-fourths. But nobody bothers looking for Camelopardalis even though it's circumpolar and thus, visible every minute of the year.

Cancer's gotta go, that's obvious, along with Scutum, which sounds like sputum.

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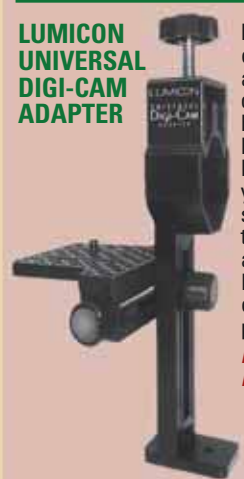

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BY GLENN CHAPLE

A star by any other name

Quick trivia question: What is the

identity of the star BD +88°8? Never heard of it? How about HD 8890, BS 424, or SAO 308? Still drawing a blank? Surely you have encountered Struve 93 or ADS 1477 during your nighttime astronomical forays. If you're still shaking your head, I have a surprise for you. All of the aforementioned codes actually are catalog names for *one* famous star. The answer appears later in this column. First, let's look into how star names originally were documented.

A few months ago, I received an e-mail from New York reader Christine Unger, asking, "How is it possible to have the same star in two different constellations?" She was referring to a map in my October 2004 column ("Gettin' shapes") showing two stars labeled "Alpha" — one in Triangulum and the other in Andromeda. Well, Christine, it wasn't a typo.

The brightest stars have proper names, often dating back to antiquity. Tonight, we can gaze skyward at Sirius and Procyon (named by the ancient Greeks), Betelgeuse and Aldebaran (Arabic names). For anyone interested in the origin of star names, I highly recommend *Star Names: Their Lore and Meaning*, by Richard Hinckley Allen (Dover Publications, New York, 1963). This classic work was first published more than a century ago and is one of my favorite astronomy references.

Mapping the sky

Credit German astronomer Johann Bayer for the "Alphas" in Triangulum and Andromeda. In 1603, he published his landmark celestial atlas, *Uranometria*, in which the stars in each constellation usually were assigned letters from the Greek alphabet. Alpha (α) went to the brightest star, Beta (β) to the next brightest, and so on through Omega (ω).

A star's complete Bayer designation includes its Greek letter, followed by the genitive form of its parent constellation. The two "Alphas" Christine saw on the chart are properly called Alpha (α) Trianguli and Alpha (α) Andromedae.

BD +88°8 SHINES at 2nd magnitude, 7 magnitudes brighter than its companion star.

BILL AND SALLY FLETCHER

What happens in constellations whose naked-eye stars outnumber the 24 letters of the Greek alphabet? In the early 18th century, English astronomer John Flamsteed compiled a catalog of stars — *Atlas Coelestis*. This catalog, published in 1725 after Flamsteed's death, is one of the first atlases that uses equatorial coordinates (see "The golden age of star maps," December 2004). A later French edition of this catalog assigned numbers to the stars in the original *Atlas Coelestis*.

You may be wondering about those companies that allow you to name a star for a fee. Beware: The star name you pay for is *not recognized* by the International Astronomical Union — the organization that, among other things, officially names celestial bodies. My suggestion? Instead of spending your money on just one star, invest in binoculars or a telescope. Then, you'll "own" all the stars you could ask for!

And the answer is...

Now for the answer to our trivia question. Our mystery star is Alpha (α) Ursae Minoris, better known as Polaris, the North Star. BD +88°8, HD 8890, BS 424, and SAO 308 are names for Polaris from various star catalogs, while Struve 93 and ADS 1477 are its designations in double-star catalogs.

As a double star, Polaris offers an observing challenge to any small telescope owner — especially for the standard 2.4-inch refractor so many of us own. Often, a double star is hard to "split" because its member stars are close together. Not so with Polaris. Its components are separated by 18" — a vast gulf as double stars go.

But its companion is a full 7 magnitudes (630 times) fainter than the main star and often is hidden by Polaris' glare. Wait for an evening when the stars are shining steadily (good "seeing" conditions), and use a magnification of at least 100x to attempt to split these two stars.

"That which we call a rose, by any other name would smell as sweet." I doubt William Shakespeare had astronomical objects in mind when he penned these lines, but his words certainly can apply to star names. Whether you refer to it as BD +88°8, HD 8890, BS 424, SAO 308, Struve 93, ADS 1477, Polaris, or Alpha (α) Ursae Minoris, our noble North Star is a worthy target for your telescope.

Questions, comments, or suggestions? E-mail me at *gchaple@hotmail.com*.

Next month: March Madness brings the Moon, Mercury, and Messier Marathon 2005. Clear Skies.

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BY WILLIAM SCHOMAKER

Chris McKay

Periodic, self-imposed exile to the most desolate patches on Earth has been a way of life for Chris McKay for 2 decades now. But it's not wanderlust that keeps calling McKay back to Antarctica, the Siberian Arctic, Mongolia's Gobi Desert, and South America's Atacama Desert. It's Mars.

A planetary scientist with the NASA-Ames Research Center at Moffett Field, California, McKay probes extreme terrestrial boundaries to gauge life's chances for survival on neighboring worlds.

Soon, scientists like McKay will determine if Mars currently harbors life, once harbored life, or if it has been exanimate from the get-go. The answer, McKay asserts, will be rife with implications.

McKay has been involved in planning many Mars missions throughout his career, including future missions with human settlement in mind. He says that any human vying to be the first earthling on Mars likely will be trumped by a plant.

How is Chile's Atacama Desert better for preparing Mars missions than the Moon?

Clearly, the most interesting science question on Mars is the question of life. So it really boils down to the simple fact that studies of life on Earth in Mars-like environments will provide our best preparation for the search for life, or traces of past life, on Mars. Believe it or not, places like the Atacama Desert are much more Mars-like than anywhere on the Moon.

Life thrives in the unlikeliest of places, so how can the Atacama be so lifeless?

Certain bacteria have learned to thrive in radioactive environments, while others find success in [other] extremes. But all bacteria require liquid water to grow and reproduce, making water the essential environmental requirement for life.

CHRIS McKAY travels to such lifeless places as Antarctica to improve techniques for the search for life on other planets. NASA

In fact, the arid core of the Atacama is the only known place on Earth where the Mars Viking Landers could have landed, scooped up dirt, performed their life-detection experiments, and failed to find evidence of life.

When is too little water not enough?

Rainfall averages below 1 millimeter per year, with rainfall events separated by at least 4 years, are insufficient to support life.

If you could begin an earnest search for life on Mars how would you do it?

Mars is even drier than the driest portions of the Atacama Desert. Our work in the Atacama has convinced me that the surface of Mars today is lifeless.

This leaves two possibilities for searching for life: life thriving in subsurface water, or life dormant and frozen in the permafrost. We don't know if Mars has subsurface water, but we do know it has ice-rich permafrost.

I would propose drilling deeply into the ancient ice-rich permafrost on Mars. Specifically, I would target the southern hemisphere of Mars in the cratered regions near 180° W, 70° S. We know from spacecraft data that this location has an ice-rich subsurface. In addition, there are strong crustal magnetic features, which indicate the location has been relatively undisturbed since very early in martian history.

Who will win the race to establish the first earthling presence on Mars?

I predict that the first earthling to live and die on Mars will be a plant sent there in the next few years as part of a test to determine if life from Earth can survive on Mars. Humans always send another species first. The first earthling in space was a Russian dog named Laika.

Similarly, the first earthling to Mars will be a plant — probably an American plant, but it could well be a European plant.

How will the private space race alter the push for human exploration of Mars?

The most difficult, most expensive step in going to Mars is getting from the surface of Earth and into low-Earth orbit. I think corporate space activities probably will bring this cost down significantly.

How about other promising locales throughout the solar system?

After Mars, Europa is the world most likely to have liquid water and possibly life.

Einstein's other theory of relativity . . .
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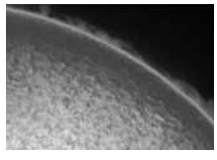

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ASTRONOMERS HAVE DETECTED X RAYS from a brown dwarf known as Gliese 569Bab. They think the emission may come from the star's corona – if so, it's the first time coronal X rays have been seen from this type of star.

news 02

Read all about it: Einstein passes a test, the Hubble Space Telescope catches a triple eclipse on Jupiter, spotting a star that fled from Tycho's 1572 supernova, and a freakishly lucky comet discovery.

GALACTIC ASTRONOMY

A hazy view of dark matter

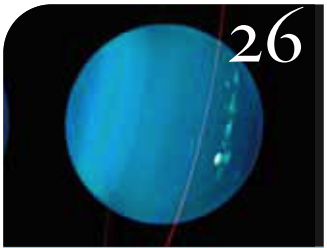
Douglas Finkbeiner (Princeton University) isn't sure what causes the microwave radiation he discovered coming from the Milky Way's center, but he thinks it may be an indirect observation of dark matter.

Finkbeiner's discovery, to be published in *The Astrophysical Journal*, came out of data from the Wilkinson Microwave Anisotropy Probe (WMAP).

In the data, Finkbeiner found an unexplainable haze surrounding the Milky Way's center. This radiation looks like what fast electrons in a magnetic field would emit — but they would have to be moving near the speed of light. This gave Finkbeiner the idea that he might have discovered the signal of dark matter.

Astronomers agree there is vastly more matter in the universe than telescopes observe. Candidates for this dark matter include subatomic particles, one of which is called the neutralino. No one knows if neutralinos exist. But if they do, Finkbeiner calculates, they should interact and accelerate other particles to extreme speeds, causing them to emit synchrotron radiation exactly like the kind WMAP detected. He also notes the way the microwaves increase toward the center of our galaxy nicely matches the expected distribution of dark matter.

Fast electrons and positrons also interact with starlight and with the cosmic background radiation itself. They kick photons up to much higher energies, so we see them as X and gamma rays. Astronomers note excess gamma rays toward the galactic center, which Finkbeiner's idea could also explain.



24 Russia plans a mission to Mars' moon Phobos
25 Dark matter wraps a solitary galaxy
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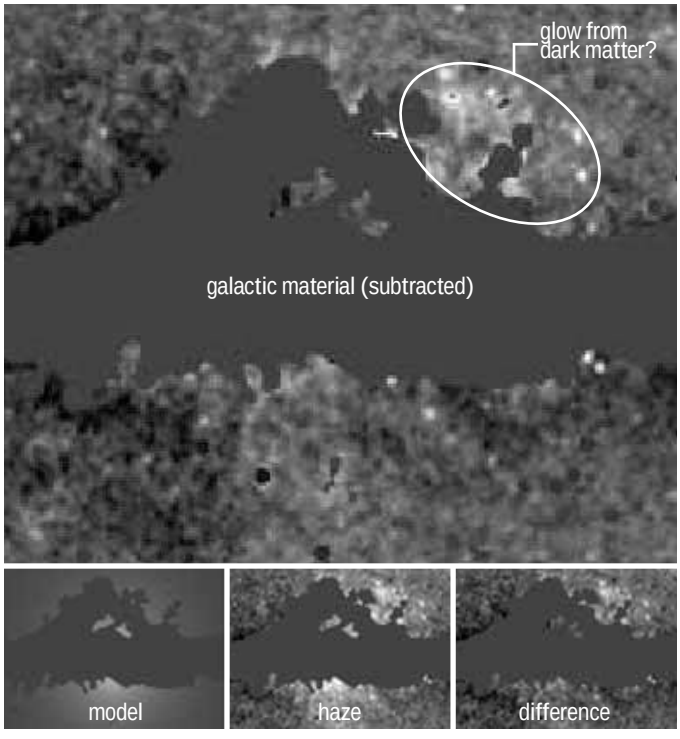

DARK GLOW. Has Milky Way dark matter been detected? Subtracting a brightness model from the haze observed to surround the center of the Milky Way leaves a glow that may come from dark matter. NASA/WMAP/PRINCETON, D. FINKBEINER

Like a cosmic mirage, Finkbeiner's haze may appear to show something not really there, but he points to observations that could confirm or refute it. Gamma rays corresponding to the annihilation of neutralinos should be detectable by the Gamma Ray Large Area Space Telescope, a satellite to be launched in 2006.

"If the haze results from dark-matter annihilation, that would be a major breakthrough in understanding what dark matter is," he says.

And finally, the neutralino may be observed in future particle colliders on Earth. A race is on to find — or dismiss — the neutralino as a component of dark matter. — BAS DEN HOND

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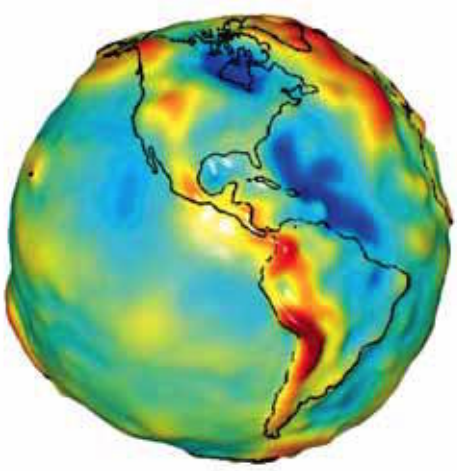


LUMPY GRAVITY. An excellent gravity model from NASA's GRACE satellite let scientists test relativity by tracking two Earth-orbiting satellites. NASA/JPL/DLR

GENERAL RELATIVITY

Einstein passes test

A distortion of space and time predicted by Albert Einstein's 1916 theory of general relativity has been detected directly for the first time, say scientists. Writing in *Nature* (October 21, 2004), Ignazio Ciufolini (University of Lecce, Italy) and Erricos C. Pavlis (University of Maryland) report measuring a relativistic distortion known as "frame-dragging."

According to general relativity, the gravity of the spinning Earth drags the space-time framework surrounding the planet forward as Earth rotates.

Says Pavlis, "The effect is like spinning a bowling ball in molasses — anything caught in the molasses moves along too." He notes calculations indicate frame-dragging from Earth's rotation could change a satellite's position by about 6 feet (2 meters) over one year.

The team tracked the two Laser Geodynamics Satellites, LAGEOS 1 and 2, for almost 11 years, subtracting distortions such as that caused by Earth's lumpy gravitational field. The effect the researchers measured has 99±5 percent the amount predicted by general relativity.

They hope to have the results confirmed by NASA's ongoing Gravity Probe B mission. "We're very satisfied with the present result," says Pavlis. — ROBERT BURNHAM

Russia prepares a return to Mars

After a decade and a half of budgetary drought, planetary scientists in Moscow are finalizing plans for an ambitious robot mission to the martian moon Phobos as early as 2009. They intend to collect soil samples (including a drill core about a yard long) and return them to Earth.

The project's name is Fobos-Grunt (*grunt* is Russian for dirt). The mission has been discussed for several years, and approval was announced in October 2004 in Vancouver, British Columbia, at the International Astronautical Congress meeting.

Lev Zelyoni, director of the Space Research Institute, says this probe is the only Russian planetary mission currently being planned.

"The project envisages constructing an interplanetary craft capable of flying to Mars, landing on Phobos, taking samples of its soil, and bringing them back to Earth," he says. About half a pound (200 to 300 grams) of soil would be returned.

"A long-lived station will remain on Phobos," he adds, "which will continue exploring it in an automatic mode. It will monitor the Mars climate and study the space around it."

This package will weigh about 110 pounds (50 kilograms), other scientists say. An American instrument may be included on the spacecraft, and a Japanese microsat may travel with it to Mars.

SAMPLE RETURN FROM MARS' MOON? Russian scientists plan to retrieve surface samples from the martian moon Phobos using technology derived from lunar sample-return missions. IKI

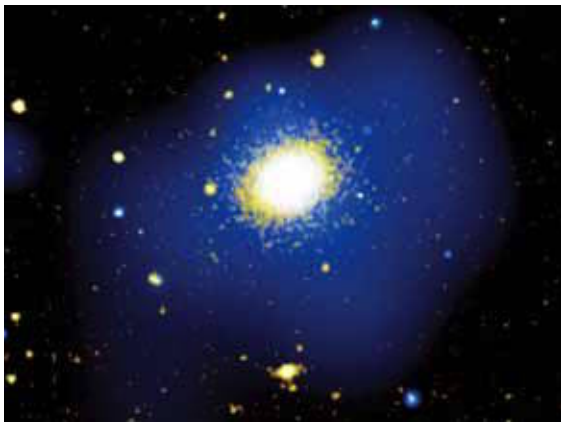
The flight plan calls for a 350-day voyage from Earth to Mars orbit, where the probe will reconnoiter the surface of Phobos and select a landing spot. After landing, the samples will be collected quickly, and the return spacecraft will blast off. This craft will then linger in Mars orbit for more than a year until a launch window opens for return to Earth.

In the early 1970s, Soviet scientists had some success with automated sample-return missions to the Moon. Because the gravity of Phobos is much lower than the Moon's, smaller, cheaper rockets can perform the mission. The same basic design for a return capsule can be used with modifications.

However, the catch is mission times are longer — about 1,000 days, much less than the 10-day lunar round-trip. Spacecraft lifetimes have always been a challenge to Russian space designers, whose equipment tends to break down sooner and more often than Western probes. But recent Russian Earth satellites have shown improved longevity.

Phobos was the target of two Russian lander probes in 1988, but one was lost en route due to a computer error, and the second went out of control during its final approach to the moonlet. The most recent Russian interplanetary probe, Mars 8, fell back to Earth shortly after launch in November 1996. It was as much the victim of severe budget cuts as of shoddy engineering. — JAMES OBERG

THE SUN HAS BEEN ABNORMALLY ACTIVE during the last 70 years, according to a study that combines tree-ring dates with carbon-isotope data. The last period of such high solar activity was more than 8,000 years ago.



DARK HALO. A solitary elliptical galaxy, NGC 4555, is surrounded by a cloud of million-degree gas (blue tint) that hints the galaxy, unlike other ellipticals, has a lot of dark matter. NASA/CXC/PALOMAR DSS

GALACTIC ASTRONOMY

Chandra finds dark matter wraps a lonely galaxy

Two astronomers using the Chandra X-ray Observatory have found a hot, X-ray-emitting gas cloud surrounding an elliptical galaxy, NGC 4555. The gas is too hot for the galaxy to hold without a dark-matter halo about 10 times the mass of the galaxy's stars. The observation, however, conflicts with optical data suggesting elliptical galaxies have little or no dark matter.

Ewan O'Sullivan (Center for Astrophysics, Cambridge, Massachusetts) and Trevor Ponman (University of Birmingham, United Kingdom) say the gas cloud has a temperature of 18 million degrees Fahrenheit (10 million kelvins). The cloud spans 400,000 light-years, roughly twice the galaxy's extent.

This raises a puzzle, however, because optical observations by Aron Romanowsky (University of Nottingham, U.K.) and collaborators in 2003 found three close-by elliptical galaxies with little evidence for dark matter. (The nature of dark matter in general remains unknown.)

NGC 4555 lies too far away for a similar optical survey. But the existence of the hot gas told O'Sullivan and Ponman that the galaxy must have a dark-matter halo.

Says O'Sullivan, "It seems a lot more work is needed on elliptical galaxies before this issue will be resolved."

The team reported the new Chandra results in the *Monthly Notices of the Royal Astronomical Society* (November 1, 2004). — R. B.

PLANETARY SCIENCE

Jupiter: triple eclipse

On March 28, 2004, the Hubble Space Telescope used its NICMOS infrared camera to observe Jupiter. It caught two jovian moons and their shadows, plus the shadow of a third moon, as they crossed the giant planet's disk. Such triple shadows occur only a couple of times each decade.

Astronomers captured the shadows with a new technique: They slewed Hubble much faster than usual and snapped many frames as the telescope swung around. They then stitched the individual snapshots into a single overall image. — R. B.

MOONS AND SPOTS. Hubble imaged shadows from three moons on Jupiter. NASA/ESA

FLEE THE SCENE. When Tycho's supernova star exploded, its companion star went flying. NASA/CXC/SAO

SUPERNOVAE

Tycho's runaway star

A team of astronomers led by Pilar Ruiz-Lapuente (University of Barcelona, Spain) has found a star fleeing through the wreckage of Tycho's supernova, which exploded in 1572.

The runaway star has a velocity about 3 times that of stars in its area and is an aging version of our Sun. The astronomers say it was once part of a binary system, hitched to a white dwarf star pulling gas from it.

When the white dwarf took in too much gas, it blew up as a Type Ia supernova, and the companion star flew off on its own. — FRANCIS REDDY

STELLAR ASTRONOMY

Beta Centauri weighs in

Beta Centauri is the 11th brightest star in the night. It lies just 4.5° west of Alpha Centauri, the Sun's nearest neighbor. Astronomers have a new and better measure of Beta Centauri's mass and distance.

Knowing a star's mass is crucial, because mass dictates how fast a star evolves and how it dies. Beta Centauri's main star contains two nearly identical blue giants that pulsate every few hours and orbit each other every 357 days.

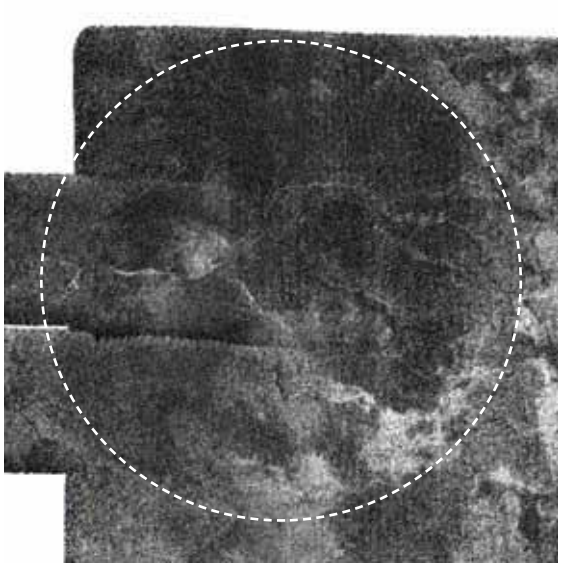
John Davis (University of Sydney) and colleagues used interferometry and spectroscopy to establish that each blue giant has 9.1 solar masses. The size of the pair's orbit yielded a distance of about 330

ALPHA, BETA, CRUX. Beta (arrow) is flanked by Alpha (left) and Crux. FRED ESPENAK

light-years, nearly 200 light-years less than the Hipparcos satellite gave. The error was likely caused by the blue giants' orbital motion.

The new distance places Beta Centauri about as far from Earth as Alpha, Beta, and Delta Crucis, the three bright stars in the Southern Cross. — KEN CROSWELL

KUIPER BELT OBJECTS MAY BE SMALLER than astronomers thought, says a new study of the object 2002 AW197. It appears more reflective (and hence smaller) than expected, implying the Kuiper Belt itself is less massive.



ICE DOME. Cassini's radar imager shows a flat lava dome (circled) on Titan resembling those on Venus, but this one is powered by molten ice, not rock. Radar illumination is from the south (bottom), so south-facing slopes appear bright. NASA/JPL

PLANETARY SCIENCE

Icy domes, flows on Titan

When the Cassini spacecraft swept past Titan October 26, its imaging radar scribed a line across that moon, piercing the haze and revealing the surface. The features it spotted include a lava dome 60 miles (100 kilometers) in diameter. The radar also detected what project scientists believe is a lava flow at least 90 miles (150 km) long. In both cases, the molten element in what scientists call cryovolcanism is ice, not rock.

The radar also revealed a long, branching feature with lobes, possibly something that welled up from a network of cracks that are hidden from the radar. This feature, together with the dome, suggests Titan is a place with some kind of volcanic activity.

At Titan's surface temperature, roughly –300° Fahrenheit (80 kelvins), ordinary ice is like steel. But Ralph Lorenz of the University of Arizona and a member of the radar team notes that "the moon's subsurface could be warmer and softer, like a Slurpee."

In radar images, bright regions are those that scatter the signal strongly back toward the spacecraft. Brightness can come from the material's physical or chemical properties, or from the ground having surfaces facing the radar the size of the radar waves. In Cassini's case, this is 2.2 centimeters, or about 1 inch. But project scientists note that clean ice containing bubbles also might make a good reflector. For now, however, surface roughness appears the most likely cause. —R. B.

PLANETARY SCIENCE

Mars' groovy moon

Phobos, the largest and innermost of the two martian moons, bears a curious resemblance to a striated potato.

Phobos, which orbits Mars 3 times a day, is about 17 by 11 miles (27 by 18 km) in size. Its most striking features are a single impact crater nearly half the moon's size named Stickney, and a puzzling, global network of grooves. The two appear related because the formation of the 6-mile-wide (10 km) Stickney, probably came close to destroying the moon.

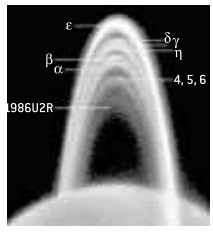
New Mars Express spacecraft images of Phobos show features in better detail than previous missions. — F. R.

POTATO MOON. Grooves hint that a big impact nearly shattered Phobos. ESA/DLR/FU BERLIN

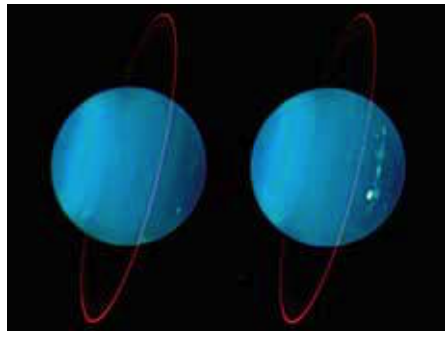
PLANETARY SCIENCE

Wacky weather

Uranus is known for being a dull, blue ball. As its southern summer ends, however, methane storms are brewing in the haze and have been caught by astronmers using the 10-meter (33 ft.) Keck Telescope. — F. R.



NEW & OLD. Infrared Keck images reveal ring features unseen since Voyager 2 in 1986. KECK/U.C. BERKELEY



RAGING METHANE. Adaptive optics on the Keck Telescope show new uranian storms. KECK/U. WISC.

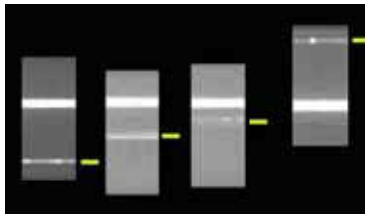
PLANETARY SCIENCE

One-in-a-trillion comet

On September 22, Sandhya Rao and Dave Turnshek, both of the University of Pittsburgh, were taking a star's spectrum at the MMT observatory in Arizona.

As their exposure of BD+30° 3639 came to an end, a new spectrum appeared on the control screen. Because the spectrograph's field of view is 2" by 2', Rao and Turnshek expected the object would vanish after the next exposure. But the next frame showed the mystery object closer to the star's position.

A quick check revealed they were seeing the object move along the instrument slit. Calculations showed it was most likely a comet or asteroid, and the object's spectrum identified it as a previously unknown 16th-magnitude comet. Despite calls to other telescopes in hopes of capturing a confirming image, the object has not been observed again. — MATTHEW KENWORTHY

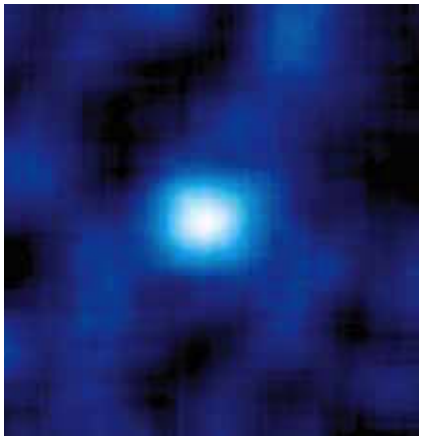


NOW TRY THE LOTTERY. Time-lapse spectra show a probable comet gliding along a spectrograph's slit. MMT/SANDHYA RAO

GALACTIC ASTRONOMY

New dwarf galaxy

A faint gathering of stars detected on the fringes of the Milky Way may be the least-luminous dwarf galaxy ever found — or it could be one of the most unusual globular clusters known. Astronomer Beth Willman (New York University) led a team that used data from the Sloan Digital Sky Survey (SDSS) to find the mysterious object.



DWARF GALAXY? Faint blue stars merge into a soft smudge in this image of Willman 1, a dwarf galaxy belonging to the Milky Way. SDSS/NYU

"We discovered it in a search for extremely dim companion galaxies to the Milky Way," she says, noting the new object, dubbed Willman 1, is 200 times less luminous than any galaxy known. Michael Blanton (NYU) says that if the object isn't a galaxy, the best alternative is an unusual kind of globular cluster. The team's report has been submitted to *The Astronomical Journal*.

Astronomers find the outskirts of nearby galaxies good hunting grounds for low-luminosity objects. Their searches bear on the question of dark matter in galaxies. The prevailing model suggests perhaps thousands of dark-matter clumps surround the Milky Way. Each clump might contain a dwarf galaxy and could span a few hundred light-years.

Says Willman, "If the new object is a dwarf galaxy, it may be the tip of a population of ultra-faint dwarf galaxies." — R. B.

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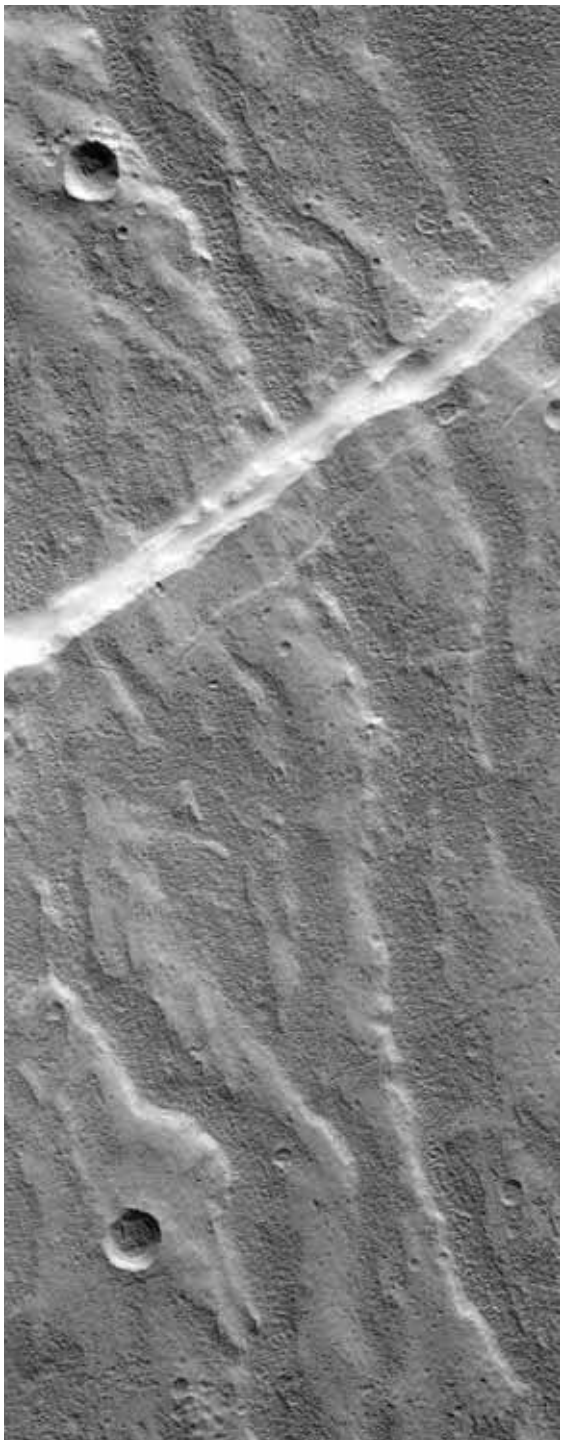
HOW FAR IS THE SUN? Astronomers measured the Earth-Sun distance using the recent transit of Venus. They found the distance to be 92,962,541 miles (149,608,708 km), just 0.007 percent larger than the accepted radar-based figure.



Lava flows on Alba Patera

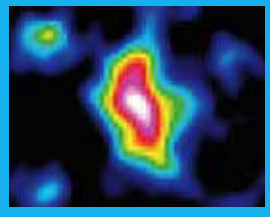
RIVULETS OF LAVA. A fault (top) cuts across lava channels on the slopes of the giant martian volcano Alba Patera. Geologists are unsure what caused the eroded, nubbly texture in the channel floors. In this image, about 1.9 miles (3 km) across, sunlight comes from the upper right. NASA/JPL/MSSS/IMAGE R12-00725

GALACTIC ASTRONOMY

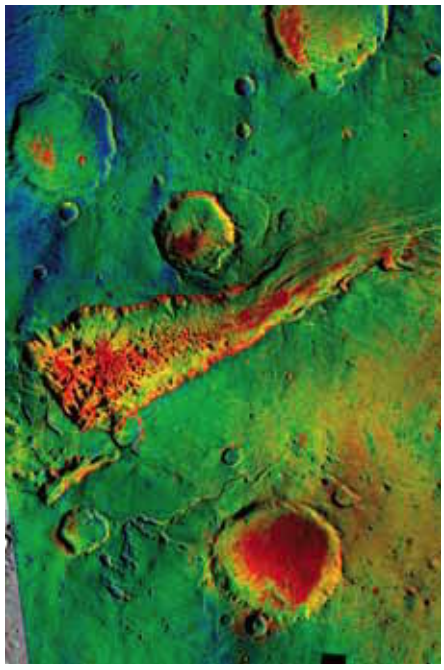
Did galaxies start with black holes?

The bigger a galaxy's central black hole, the more mass its central stellar bulge has. But does the black hole or the stellar bulge form first? New observations with the Very Large Array (VLA) radio telescope say for at least one giant galaxy, the black hole came first.

Chris Carilli (NRAO) led a study of quasar J1148+5251, the most distant known, at more than 12.8 billion light-years away. "We found lots of gas in this young galaxy, but the masses of the gas and the black hole add up to nearly the entire system's mass," says Carilli. "It's a black hole without much of a stellar bulge." — F. R.

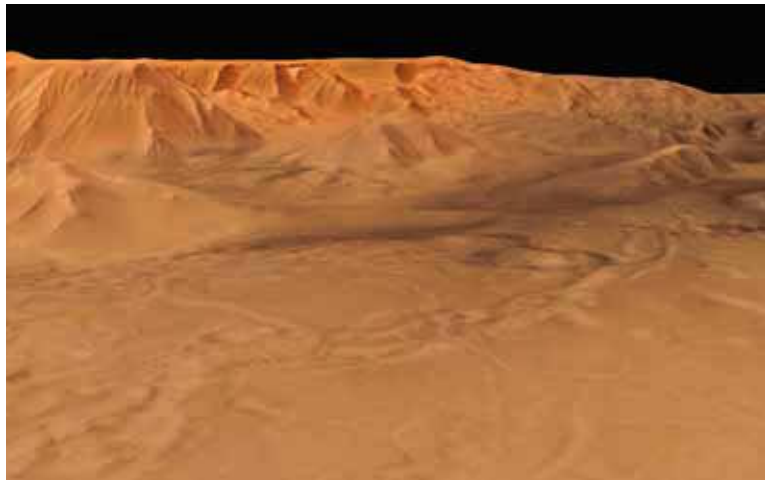


STARRY BULGE. One quasar formed a black hole before making a stellar center. NRAO



MARS PHOTOJOURNAL

WARM RUBBLE. Exposed rocks (reddish tint) line this channel floor in Aromatum Chaos and are seen also in several craters. Greenish tints show cooler and dustier regions. The image lays a Mars Odyssey nighttime infrared view over a visible-light MOC image from Mars Global Surveyor. The view is about 160 miles (260 km) wide. NASA/JPL/ASU



PLANETARY SCIENCE

Looking into Tithonium Chasma

DARK LAYERS AND GIANT CRACKS. The High-Resolution Stereo Camera on Mars Express imaged Tithonium Chasma in Valles Marineris. Rendered in 3-D, the view shows a giant polygon in the foreground and dark layers that may be volcanic. ESA/DLR/FU BERLIN

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Einstein's century

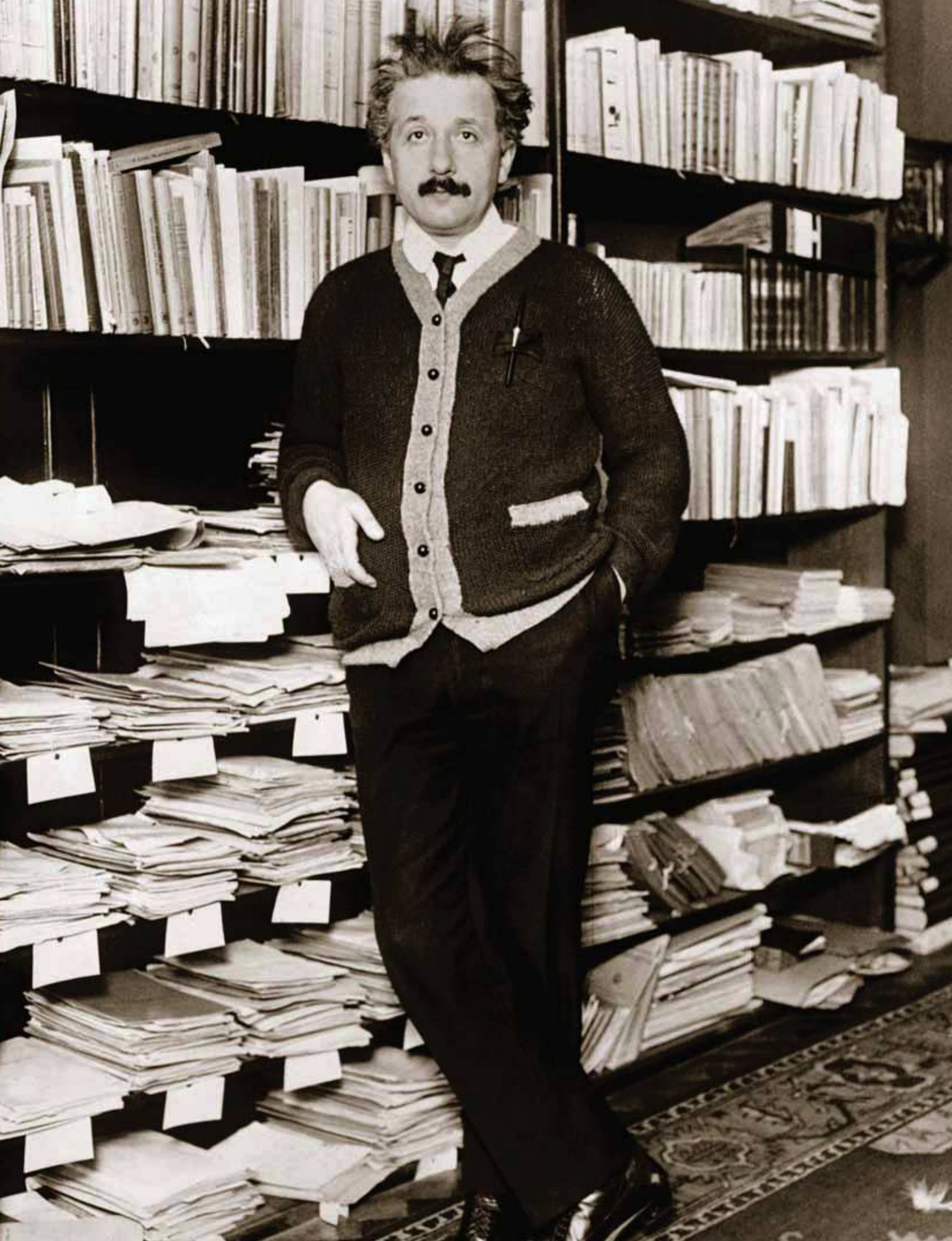
Few areas of astronomy have not felt the effects of Albert Einstein's theories. (One exception might be planetary science, which is built largely on foundations of geology and geophysics.) While Einstein's ideas grew from the physics of his day, he had the happy knack of looking at problems more directly than most of his fellow physicists did. As a result, he uncovered paradoxes they didn't perceive — and he solved them so skillfully that he put an indelible stamp on 20th-century physics.

This special issue of *Astronomy* commemorates the centennial of Einstein's landmark 1905 paper on the electrodynamics of moving bodies, or as we'd say today, the theory of special relativity. This paper, plus the others he published that year and over the following decade, rewrote the foundations of physics.

The articles that follow seek answers to three questions centering on Einstein and his theories. The first (p. 32) asks specifically, "How'd he do it?" and offers a remarkably simple and clear answer. The second story (p. 38) asks, "What was Einstein's life like?" It attempts to portray the man and his activities, both within physics and outside it. The third article (p. 46) takes a look at how astronomers, cosmologists, and physicists are testing relativity using techniques Einstein never dreamed of. It also tells how they are using relativity to explore the remarkable and beautiful universe we live in.

If anyone's name belongs on the past hundred years — and not just in physics — it's Einstein's. When it comes to matters of science, and even issues of peace and war, Einstein truly was the 20th century's Renaissance man. — *Robert Burnham*

AT HOME IN BERLIN after a visit to the United States in the early 1930s, Albert Einstein stood at the peak of his fame, having done more than anyone else alive to shape the direction of physics and astronomy. CORBIS



Albert Einstein's key breakthrough — relativity — came when he looked at a few ordinary things from a different perspective. /// BY RICHARD PANEK

Relativity turns I

How'd he do it? This question has shadowed Albert Einstein for a century. Sometimes it's rhetorical — an expression of amazement that one mind could so thoroughly and fundamentally reimagine the universe. And sometimes the question is literal — an inquiry into how Einstein arrived at his special and general theories of relativity.

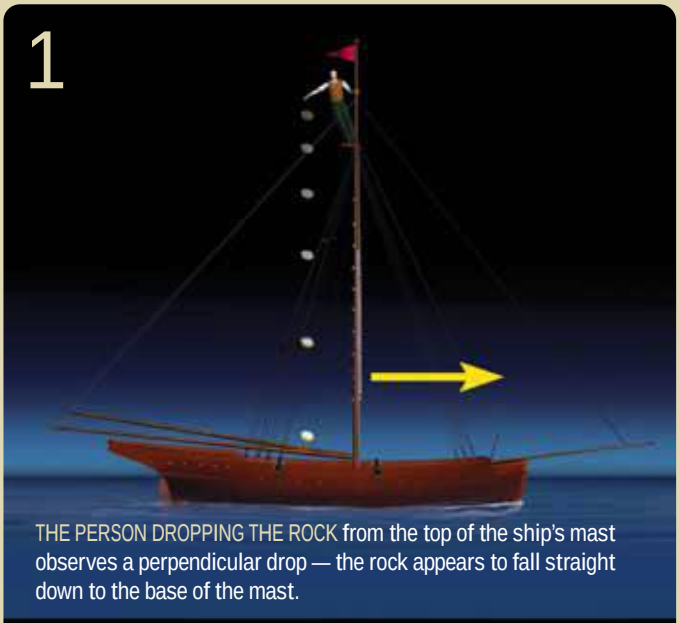
Einstein often echoed the first, awestruck form of the question when he referred to the mind's workings in general. "What, precisely, is 'thinking'?" he asked in his "Autobiographical Notes," an essay from 1946.

In somebody else's autobiographical notes, even another scientist's, this question might have been unusual. For Einstein, though, this type of question was typical. In numerous lectures and essays after he became famous as the father of relativity, Einstein began often with a meditation on how anyone could arrive at any subject, let alone an insight into the workings of the universe.

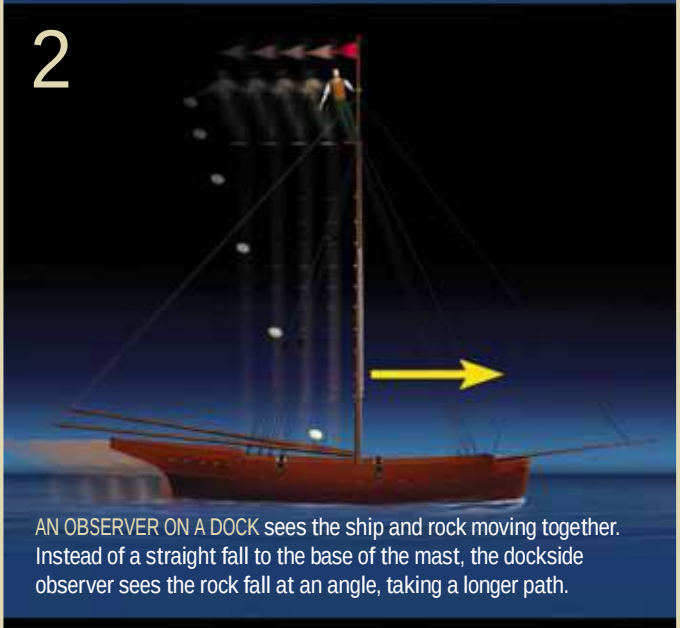
An answer to the literal question has often been equally obscure. Since Einstein emerged as a public figure, a mythology has enshrouded him: the lonely genius sitting in the patent office in Bern, Switzerland, thinking his little thought experiments until one day, suddenly, he has a "Eureka!" moment.

"Eureka!" moments young Einstein had, but they didn't come from nowhere. He understood what scientific questions he was trying to answer, where they fit within philosophical traditions, and who else was asking them. He knew which giants' shoulders he was standing on.

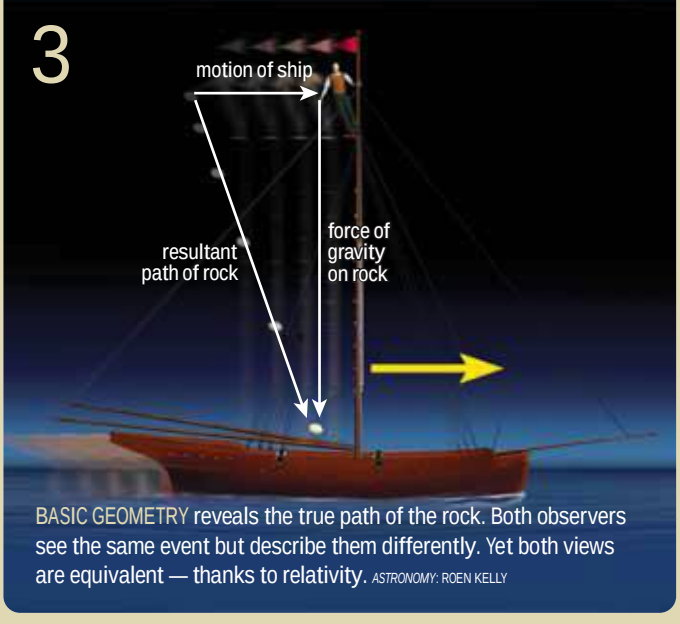
WHEN ALBERT EINSTEIN developed his theories of relativity, no one knew what galaxies were. Today, astronomers use Einstein's theories to decipher a universe filled with 100 billion galaxies and other objects not known during his lifetime. ESO



THE PERSON DROPPING THE ROCK from the top of the ship's mast observes a perpendicular drop — the rock appears to fall straight down to the base of the mast.



AN OBSERVER ON A DOCK sees the ship and rock moving together. Instead of a straight fall to the base of the mast, the dockside observer sees the rock fall at an angle, taking a longer path.



BASIC GEOMETRY reveals the true path of the rock. Both observers see the same event but describe them differently. Yet both views are equivalent — thanks to relativity. ASTRONOMY: ROEN KELLY

For Einstein, the answer to how anyone could do what he did might have been, "Who knows?" But the answer to how Einstein did what he did is simple: Here's how.

Space and time

The problem was space. When Einstein finally solved it in the spring of 1905, he had already been thinking about it for 10 years. But the problem had been around for nearly 3 centuries, since the modern scientific era dawned.

In 1632, in *Dialogue Concerning the Two Chief World Systems*, Galileo Galilei tried to explain how a Copernican view of the universe alters physics. He invited you to imagine yourself on a dock, observing a ship moving at a steady rate across your line of vision.

If someone at the top of the ship's mast dropped a rock, where would it land? At the base of the mast? Or would it land some small distance *behind* the mast — a distance corresponding to the distance the ship covers between the release of the rock at the top of the mast and its arrival on the deck?

The intuitive, Aristotelian answer is a small distance back. The correct, counterintuitive — and, Galileo argued, Copernican — answer is the base of the mast, because the movement of the ship and the movement of the rock together comprise *a single motion*.

From an observer's point of view at the top of the mast, the rock's motion seems to be a perpendicular drop — the kind Aristotle argued a rock would make in seeking to return to its natural place in the universe, the ground. A person at the ship mast's top would take into account only the rock's motion.

But for you, observing from the dock, both the rock *and* the ship would be moving, and *together*, those movements constitute a single system in motion. To you, therefore, the motion of the rock falling toward the ship would not seem perpendicular but at an angle.

And vice versa. If, instead, you the observer standing on the dock dropped a rock, then, to you, the motion of that rock relative to Earth would appear perpendicular, while to an observer on the ship, the trajectory of the rock would make an angle.

Either way, to trace the rock's trajectory would require just basic geometry, and you on the dock or the observer on the ship would have equal claim to being right. And there you have it — a 3-century-old Galilean principle of relativity.

Einstein, however, introduced a complication into this scenario: What if the object descending from the top of the mast wasn't a rock but a beam of light?

His choice of falling object wasn't arbitrary. According to the electromagnetic theory that Scottish-born physicist James Clerk Maxwell devised 40 years earlier, the speed of light is constant. It's the same no matter what. What changes isn't the speed of the light waves but their frequency — the number of waves that reaches you in a certain length of time.

Part of Einstein's larger ambition was to reconcile electromagnetism with Galileo's version of relativity. And one night in May 1905, after discussing the problem with his longtime friend and patent office sounding-board, Michele Besso, Einstein understood how to do it.

Richard Panek *is a science writer who probes the universe from New York City. His latest book is* The Invisible Century *(Viking Penguin, 2004), from which this article is adapted.*

"Thank you!" Einstein greeted Besso the following morning. "I have completely solved the problem." The trouble with the current conception of the universe, he explained, wasn't space. It was time.

Time changes

Go back to the dock and look at Galileo's ship, still in harbor after all these centuries. While it's at rest in the water, you on the dock and an observer on the ship measure the mast and agree it is 186,282 miles high. (It's a very tall ship.)

Now suppose that, as in the earlier example, the ship is moving at a constant speed across your line of sight. If the person at the mast's top sends a light signal straight down, where will it land?

The Aristotelian answer is some distance behind the mast's base. The Galilean answer is the base of the mast — which is the Einsteinian answer as well.

From your point of view on the dock, the base of the mast will have moved out from under the top of the mast during the light beam's descent, just as it did during the rock's descent. This means the distance the light has traveled, from your point of view, has lengthened. It's not 186,282 miles. It's more.

You can easily find how much more by measuring the light's journey time — and this is where Einstein's interpretation begins to depart from Galileo's.

Any velocity is distance divided by time — for instance, miles divided by seconds. In the case of light, though, the velocity isn't just 186,282 miles per second; according to Maxwell, and now Einstein, it's *always* 186,282 miles per second. It's a constant. It's on one side of the equal sign, moving at its imperturbable rate.

On the other side of the equal sign are the parts of the equation that can vary: distance and time. They can undergo infinite changes in value, so long as they continue to divide in such a way that the result is 186,282 miles per second. Change the distance the light beam travels, as happened from your point of view on the dock when the light beam on the moving ship "fell" from the top of the mast, and you have to change the time.

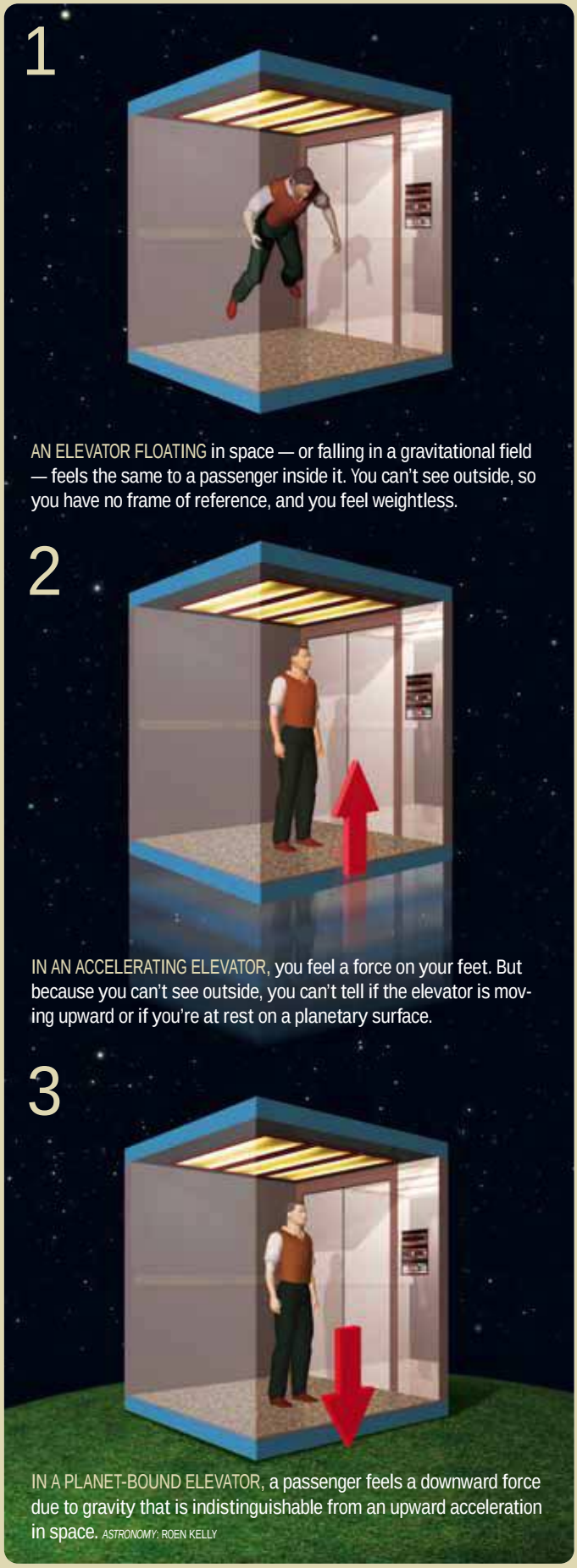
You have to change the time.

"The step," Einstein called this insight later, as if it had been merely a matter of putting one foot in front of another.

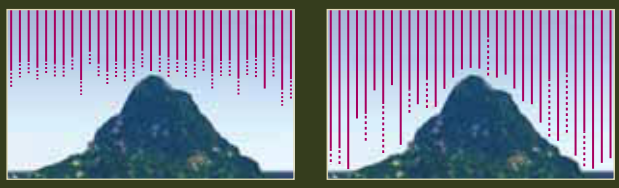
And one person, in fact, already had arrived at the idea that time might differ for different observers: Henri Poincaré, probably the most eminent mathematician of the day — and one of the two sets of shoulders on which Einstein rested. As a member of the French Bureau des Longitudes and a professor at the École Professionelle Supérieure des Postes et Télégraphes, Poincaré presided over one of the most pressing practical matters at the turn of the 20th century: the coordination of clocks, specifically, the coordination of electrical clocks.

Unlike mechanical clocks, electrical clocks allowed the transmission of information from city to city, capital to capital, even shore to ship once radio signals came into use, and all at the speed of light. Poincaré understood that this speed is a natural limit in the transmission and reception of information. In 1898, he published an essay on the subject, "The Measure of Time."

Poincaré described how a geographer or navigator wanting to know the time in Paris without being in Paris could rely on the transmission of a telegraphic signal. "It is clear first that the reception of the signal at Berlin, for instance, is after the sending of this same signal from Paris," he wrote. "But how much after?


1
AN ELEVATOR FLOATING in space — or falling in a gravitational field — feels the same to a passenger inside it. You can't see outside, so you have no frame of reference, and you feel weightless.
2
IN AN ACCELERATING ELEVATOR, you feel a force on your feet. But because you can't see outside, you can't tell if the elevator is moving upward or if you're at rest on a planetary surface.
3
IN A PLANET-BOUND ELEVATOR, a passenger feels a downward force due to gravity that is indistinguishable from an upward acceleration in space. ASTRONOMY: ROEN KELLY

RELATIVITY IN ACTION



COSMIC-RAY MUONS live longer than they should. Particles detected on a mountaintop should decay before reaching sea level. Yet many survive all the way down. Why? Because they are moving at 99.94 percent of the speed of light, the particles' decay "clock" runs slower, thanks to relativity's time-dilation effect. *ASTRONOMY:* ROEN KELLY

In general, the duration of the transmission is neglected and the two events are regarded as simultaneous."

Two years later, in another essay, and then 4 years after that, in an address at the World's Fair in St. Louis, Poincaré invited his audience to join him in imagining two observers trying to synchronize their clocks using light signals. "The clocks synchronized in that matter will not mark the true time," he said, "but what one might call 'local time,' so that one of them is slow with regard to the other. This does not matter much," he added, almost as an afterthought, yet fatally, "as we have no way of determining it." "It" was how much they differed.

Einstein replied, in effect, "What if we do have a way of determining it? Then what happens to physics?" His answer did funny things to time and, by extension, to the lengths of objects aboard the ship from your point of view on the dock (or vice versa).

Power of preconceptions

Had Einstein absorbed the demands of an emerging conception of the universe more thoroughly than Poincaré? As part of Einstein's work in the patent office, he routinely came across applications for components of clock-coordination systems.

In May 1905, Einstein moved his family from a central section of Bern, where the clocks in the towers were tethered electronically to a "master clock." He settled in an outlying neighborhood from where he could see the tower in the suburb of Muri, where the clocks were not tied to the master clock.

As Einstein later reported, "An analysis of the concept of time was my solution."

So why Einstein and not Poincaré? Poincaré himself once hinted at a possible reason. Reflecting on the scientific process, Poincaré wrote, "We must, for example, use language, and our language is necessarily steeped in preconceived ideas. Only they are unconscious preconceived ideas, which are a thousand times the most dangerous of all."

When Poincaré came to the topic of time, this proved to be the obstacle he couldn't overcome. As Einstein later wrote, the illusion of absolute time, of simultaneity, "unrecognizably was anchored in the unconscious."

Einstein's triumph in his first foray into relativity was not to invent the concept of local time. Instead, it was to take that concept more seriously than even his most adventurous peers — to elevate it, in effect, to the level of physical reality.

Bending light

If it was a triumph, his foray nonetheless wasn't wholly satisfactory. Einstein understood that all he'd done was describe a mathematical relationship between a body at rest and a body moving at a uniform — or non-changing — velocity.

What about a body at rest and one moving at a non-uniform velocity? What about a body that's in the grip of gravity?

In November 1907, he was still a patent clerk in Bern and his first paper on relativity had attracted the attention of a few influential physicists but not yet the world. Now, the editor of the *Yearbook on Relativity and Electronics* invited Einstein to summarize and elaborate on that earlier work. And so Einstein used his time at the patent office to daydream about physics.

That's when his mind's eye saw another vision. Not a beam of light descending from a mast, but a man descending from a roof.

What's the difference? Unlike the beam of light, which moves at a constant velocity, the falling man would be accelerating. But in another sense, he would also be at rest. Throughout the universe, every scrap of matter would be exerting its exquisitely predictable influence on him. Most influential, of course, was Earth, toward which he was arcing at the moment.

But he was also being pulled by the roof, the Moon, the Sun, even the stars at their unimaginable distances, as well as whatever else might lie beyond them. Yet add these forces up, and what the man in free fall would feel was nothing.

This was Einstein's key insight, what he later called "the most fortunate thought of my life" — the effects of acceleration and gravitation canceling each other out.

Just as someone aboard the old Galilean ship would have as much right to think of the dock leaving the ship as the ship leaving the dock, so the man in free fall from the roof would have as much right to think of himself at rest and the remainder of the universe in a state of motion. What would seem like gravity to an observer on the roof (or on the ground) would seem like inertia to the falling man — and both would be right.

And there we have it — another principle of relativity.

A moving elevator

As was the case in 1905, this insight didn't come out of nowhere. Einstein had been thinking about a suggestion that every atom in the universe exerts a gravitational effect on every other atom.

Einstein later dubbed this idea "Mach's principle," after Austrian physicist and philosopher Ernst Mach. (He was the second giant on whose shoulders Einstein admittedly rested.) Before mailing off his article to the editor of the *Yearbook* in December 1907, Einstein added a section expressing his hope to extend his earlier ideas on a highly specialized (hence special, as in special theory of relativity) circumstance to the universe in general (hence general relativity).

During the following 10 years, Einstein frequently returned to this problem; after 1911, his work on it became all-consuming. Once during this period, he went mountain climbing with French-Polish chemist Marie Curie. Seemingly oblivious to the crevasses as well as to her difficulty in understanding his German, Einstein spent much of the time talking about gravitation. "You understand," Einstein said to her, suddenly gripping her arm, "what I need to know is exactly what happens when an elevator falls into emptiness."

In Einstein's imagination, the motions of a hypothetical elevator had replaced the earlier free-falling man. He had taken that imaginary man out of the imaginary, resistance-free air and locked him inside an imaginary laboratory, there to arrive (with Einstein's help) at real results.

Upright in the elevator, seemingly at rest, the man would have no way of knowing whether he was experiencing gravitation or acceleration. He wouldn't know whether the elevator was standing on Earth's surface or, assuming it was moving at the proper rate (approximately 32 feet per second squared, the gravitational force at the surface of Earth), rising through space. What the man would feel would be identical in either circumstance — a perfect illustration of the principle of equivalence Einstein had intuited while sitting at his desk in 1907.

For argument's sake, Einstein imagined the elevator was rising — that it was hooked at the top onto some giant crane pulling it upward through space. Next, Einstein imagined a beam of light piercing the moving elevator — entering through one wall, passing through the compartment, and exiting the opposite wall.

If the elevator rose relative to the light source, Einstein concluded, the height from the floor at which the light entered would not be the same height at which it exited on the other side. From the passenger's point of view, the light would appear to bend.

Then, also for the sake of argument, Einstein imagined that the elevator was not rising. He imagined it was stationary on Earth's surface. Then he asked himself: Because the two circumstances were supposedly the same, wouldn't the same effect hold true for both? In other words, doesn't gravity bend light?

It took until November 1915 for Einstein to work out the mathematics to support this insight. Not until 1919 would two eclipse expeditions, expressly mounted to observe starlight as it passed near the great gravitational maw of the Sun, offer proof of this effect. But, just as in the case with Poincaré's ideas of time, Einstein's triumph was to take the concept of gravity more seriously than even his most radical peers and to elevate it to the level of physical reality.

Building ideas

Einstein readily acknowledged the influence of Poincaré and, especially, Mach. Neither returned the compliment.

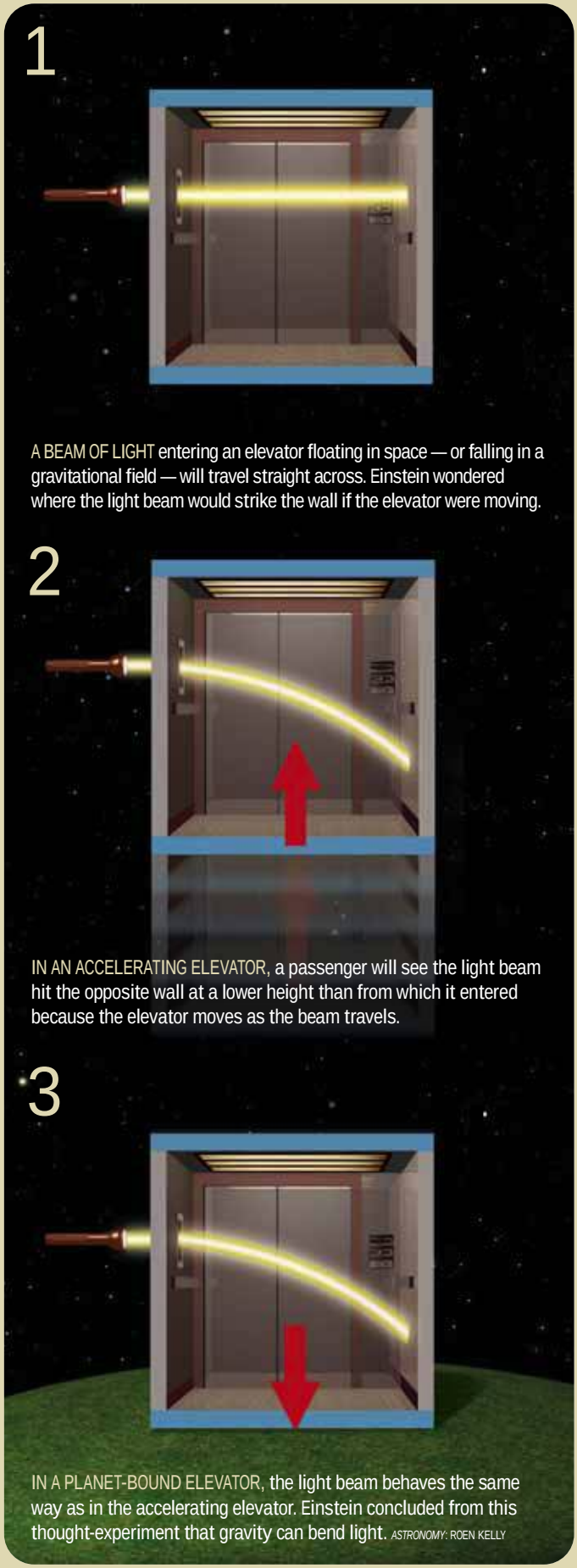
Poincaré, who died in 1912, didn't deign to comment on Einstein's special theory except in one dismissive reference. Likewise Mach: Einstein visited him in the autumn of 1913 and felt their meeting had gone well. Einstein learned 9 years later that after their meeting, Mach had declared he would refute relativity, a promise he didn't live long enough to fulfill.

From a century's distance, the opinions of these influential figures regarding Einstein are little more than footnotes for historians. What remains significant is the influences were there, as Einstein acknowledged.

The influences didn't arise as bolts from the blue, munificence from the muses. They arose, rather, in a deliberate fashion, one great mind building upon another.

The story of Einstein's relationship to relativity should not be a myth haunting future generations. Instead, it should serve as an inspiration, a living example that one mind can ask and answer profound questions about the universe.

How'd he do it? *That's* how.



A BEAM OF LIGHT entering an elevator floating in space — or falling in a gravitational field — will travel straight across. Einstein wondered where the light beam would strike the wall if the elevator were moving.

IN AN ACCELERATING ELEVATOR, a passenger will see the light beam hit the opposite wall at a lower height than from which it entered because the elevator moves as the beam travels.

IN A PLANET-BOUND ELEVATOR, the light beam behaves the same way as in the accelerating elevator. Einstein concluded from this thought-experiment that gravity can bend light. ASTRONOMY: ROEN KELLY

The man who remade th

His theories of relativity made Albert Einstein the most famous scientist in the world. Yet his life

THE ALBERT EINSTEIN ARCHIVES

THE ALBERT EINSTEIN ARCHIVES

ULLSTEIN - ULLSTEIN BILD

CORBIS

1880s EINSTEIN'S FAMILY was close-knit and generally cheerful despite the business failures of his father, Hermann (*upper left*). His mother, Pauline (*upper right*), strongly encouraged him in music, which he (*center*) found relaxing in later years. His sister, Maja (*lower right, pictured with young Albert*), was 2 years younger than him.

IMAGE ARCHIVE ETH-BIBLIOTHEK, ZURICH

1890s IN HIGH SCHOOL, Einstein (*seated at left*) had little patience for regimented school life, and his teachers thought he'd probably fail at whatever he did.

1905 EINSTEIN ACTUALLY ENJOYED parts of his job as technical expert, third class, at the Swiss patent office. It forced him to assess quickly the physical principles underpinning inventions. Just months after publishing his revolutionary papers outlining his special theory of relativity, Einstein was promoted to technical expert, second class.

e universe

involved more than physics. /// BY ROBERT BURNHAM

THE ARCHIVES, CALIFORNIA INSTITUTE OF TECHNOLOGY

1900s BERN'S CLOCK TOWER, seen here, got Einstein thinking about how time and space relate.

AIP EMILIO SEGRÈ VISUAL ARCHIVES

1911 BEFORE THE PUBLIC KNEW HIM, Einstein had already begun to make an impact on physics. In Brussels, Belgium, at the first Solvay Conference in Physics, Einstein (*second from right*) mingled with other greats, such as Marie Curie and Ernest Rutherford. Here, Rutherford (*fourth from the right*) stands behind Curie, who's seated at the table.

BENJAMIN COUPRIE/INST. INT. DE PHYSIQUE SOLVAY/AIP EMILIO SEGRÈ VISUAL ARCHIVES

Albert Einstein was the greatest scientific genius

since Isaac Newton. But he did have his share of problems.

There were difficulties in school and difficulties with mathematics, yes — but also difficulties with authorities, with women, and with politicians. A genius he was, but a very human one, and that makes him a figure many can identify with.

Despite this, his signature theory — relativity — is almost flagrantly anti-popular. It tells us the universe is not as we intuitively perceive. It takes us out of the everyday world of our senses and throws us into a universe where light bends with space and where "simultaneous" needs careful definition. Further, if physical laws run the same everywhere, time manifestly does not.

Perhaps the most remarkable thing about Albert Einstein is how little his childhood foretold what was to come.

The man who gave relativity to the world and reshaped our understanding of it was born in the small south-German city of Ulm March 14, 1879. In 1880, his family moved to Munich after his father's electrical technology business failed. In 1881, Einstein's only sibling, a sister named Maja, was born.

Einstein's father encouraged his interests in the natural world as did his mother in matters of culture, primarily music. His uncles on both sides of the family fostered an interest in mathematics and mechanical devices.

In 1884, Albert's father gave him a small magnetic compass. The boy was fascinated as the needle, sealed off from the outside world, nevertheless responded to something that made it always point north. A model steam engine from his uncle similarly captivated him.

While Einstein received training in Judaism at home, his family was not strongly religious. In fact, the first elementary school he attended was Roman Catholic — located about a 20-minute walk from the Einstein home.

In school, Einstein stood apart from other students. He was slow in learning to talk, speaking with noticeable hesitation as late as 9 years old. He had little interest in things apart from science and mathematics. More significantly, he rebelled, both quietly and openly, against the regimentation and authority common in German schools at the time.

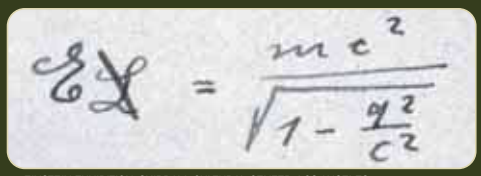
Perhaps the most useful thing he learned in school was to think things through for himself. Years later he said, "A normal adult never stops to think about problems of space and time. ... But my intellectual development was retarded ... so naturally I could go deeper into the problem than a child of normal abilities."

When Einstein was 17, he decided to attend the Federal Polytechnic Institute in Zurich, Switzerland. However, he failed the entrance exam and did a makeup year at the Aarau Cantonal School. When he applied the second time, the institute admitted him.

On graduation in 1900, he applied to become an assistant professor of physics but was turned down. He took a part-time teaching job at a school in Schaffhausen, Switzerland, and became a Swiss citizen. A little later, he landed a full-time job as a technical expert, third class, at the Swiss patent

ULLSTEIN - ULLSTEIN BILD

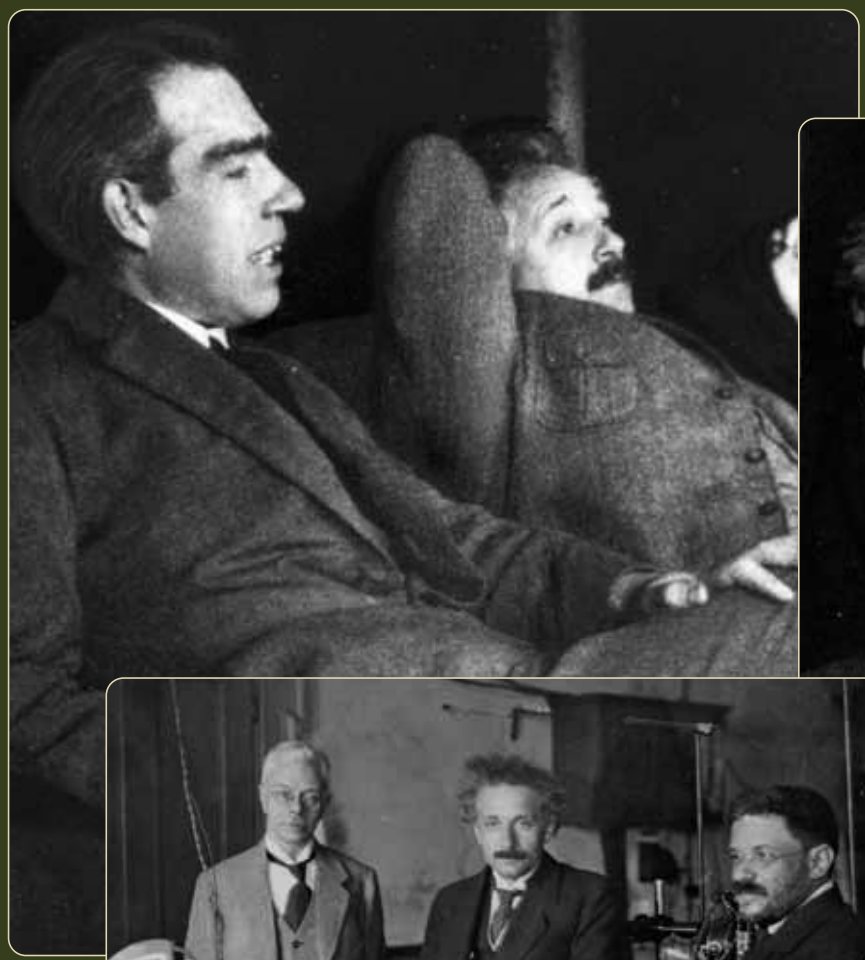
1919 BY AGE 40, Einstein was already considered one of history's all-time great geniuses. The caption for this image on the cover of the German magazine *Berliner Illustrirte Zeitung* reads: "A new celebrity in world history: Albert Einstein. His research signifies a complete revolution in our concepts of nature and is on par with the insights of Copernicus, Kepler, and Newton."



EINSTEIN EXHIBITION, SKIRBALL CULTURAL CENTER, LOS ANGELES

1907 HISTORY'S MOST FAMOUS equation appears in an article by Einstein. The potential of "energy equals mass multiplied by the speed of light squared" was not realized until the discovery of nuclear fission in the 1930s.

Niels Bohr (*left*) and Einstein (*right*)



PAUL EHRENFEST/AIP EMILIO SEGRÈ VISUAL ARCHIVES

AIP EMILIO SEGRÈ VISUAL ARCHIVES

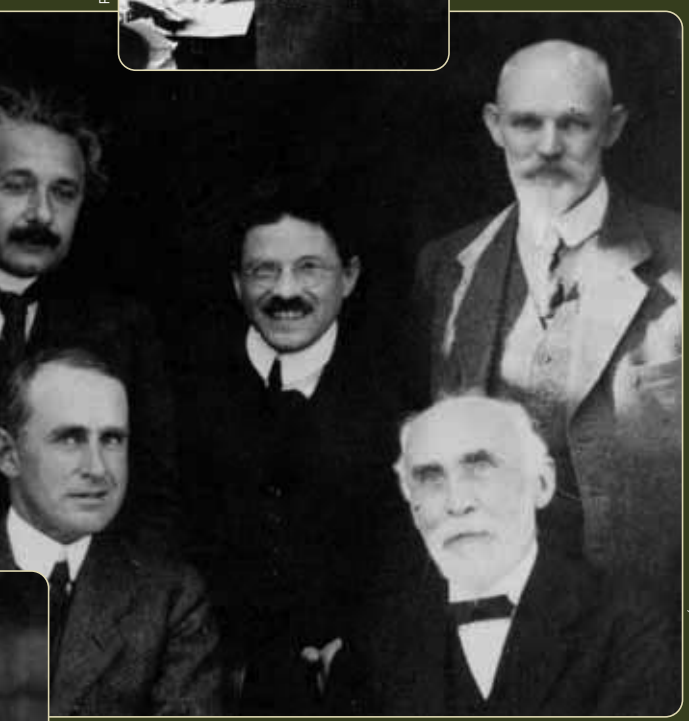
1920s EINSTEIN'S FAME WAS ASSURED, but his ideas began to diverge from those advocated by other, and younger, physicists. Many prominent international physicists were frustrated with Einstein when he didn't accept the chance-dominated physics they saw so clearly. Here, Einstein converses with 1902 Nobel Prize winner in physics Pieter Zeeman (*left*) and Austrian physicist Paul Ehrenfest (*right*) in Zeeman's laboratory in Amsterdam.

AIP EMILIO SEGRÈ VISUAL ARCHIVES

1919 WHEN HE MARRIED HIS COUSIN ELSA, Einstein found someone who looked after his needs without the stress and strife he had in his first marriage.

PAUL EHRENFEST/AIP EMILIO SEGRÈ VISUAL ARCHIVES

Einstein (*left*)
Wolfgang Pauli (*right*)



AIP EMILIO SEGRÈ VISUAL ARCHIVES

Back row, left to right: Einstein, Paul Ehrenfest, Willem de Sitter
Front row, left to right: Arthur S. Eddington, Hendrik A. Lorentz

REV. CARRIÈRE/ECOLE BIBLIQUE, JERUSALEM

1923 POLITICAL AND SOCIAL ACTIVITIES increasingly occupied Einstein in the 1920s and 1930s. He traveled to Jerusalem in February in support of Zionist goals. Here, he has lunch at the British High Commissioner's residence.

office in Bern. In 1903, he married Mileva Maric, who had been a mathematics and physics student at the Polytechnic Institute at the same time he was.

Meanwhile, Einstein continued to think about physics and kept abreast of developments, although he was virtually unknown within the community of contemporary physicists. But his reading and thinking paid off in 1905. That was his *annus mirabilis*, the "miracle year" when he published four epochal papers and finished his Ph.D. dissertation at the University of Zurich. (In addition, he published two more important papers in early 1906.)

Such a bursting-forth was almost unheard of. Only one other such period comes to mind: 1665–66, when Isaac Newton conceived the idea of universal gravity, discovered that white light is made up of all colors together, and invented calculus — at the age of 23.

The subjects of Einstein's four 1905 papers spanned a broad range. His first paper explained the photoelectric effect (light interacts with matter as if light were packets of energy). His second paper explained the cause of Brownian motion (heat is produced by molecular movements).

He proposed a special theory of relativity (saying space and time cannot be separated), and he claimed that mass and energy were equivalent. (This last paper contains the famous formula that, in modern notation, would be written as $E=mc^2$.) *Any* of these papers would make a great career, let alone all of them.

In 1906, in acknowledgement of his successful Ph.D. dissertation in January, the patent office promoted Einstein to technical expert, second class.

Science and politics

Einstein's fame was growing quickly within the world of physics, and the next decade saw increasingly prestigious university appointments and even his first honorary degree. Meanwhile, he was taking deeper interest in politics and world affairs, including Zionism.

When World War I broke out in 1914, Einstein was a professor at the University of Berlin. Disgusted by the war and eagerness of many of his fellow scientists to work on military projects, he became a pacifist.

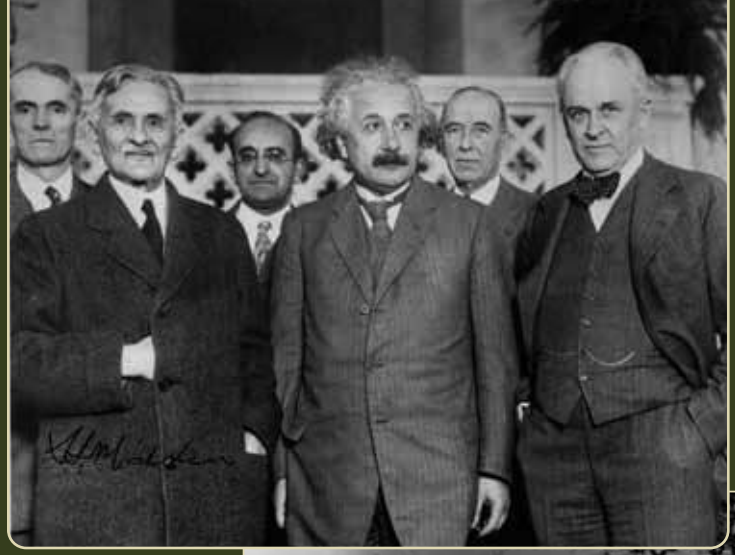
He signed anti-war manifestos and lent support to those working to end the war. Einstein had to step carefully, however, because he was Swiss. In fact, German military authorities noted his anti-war activity and quietly placed his name on a list of 30 pacifists who weren't allowed to leave the country without permission.

With the war grinding on, Einstein immersed himself in theoretical physics, developing his ideas on relativity and shaping them into a generalized theory of relativity that encompassed gravity. (See "Relativity turns 100," page 32.)

After much work and numerous false starts, the theory was published in 1916. Word of it spread slowly outside of Germany due to the war.

Less than a year after the war, however, one of general relativity's predictions — the bending of light by gravity — was

Robert Burnham *is a senior editor of* Astronomy.



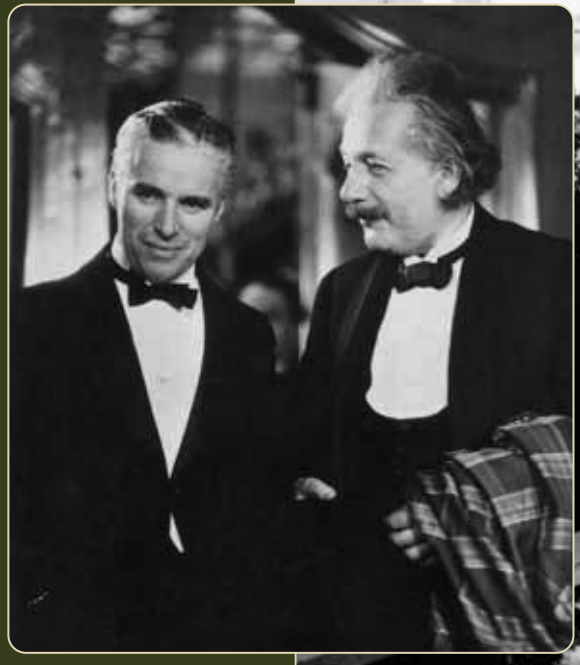
WILLIAM KELLOGG/AIP EMILIO SEGRÈ VISUAL ARCHIVES

Back row, left to right: Walter Adams, Walther Mayer, Max Ferrand
Front row, left to right: Albert Michelson, Einstein, Robert Millikan

1930s A WORLD-FAMOUS FIGURE, Einstein spent part of the years 1930 to 1932 in the United States, where he visited Caltech in Pasadena, California, and Mt. Wilson Observatory (*below*). Besides spending time with noted scientists (*left and below*), Einstein also hobnobbed with celebrities such as Charlie Chaplin (*lower left*).

THE ARCHIVES, CALIFORNIA INSTITUTE OF TECHNOLOGY

THIS EINSTEIN caricature by British editorial cartoonist David Low was published in 1933.



GRANGER COLLECTIONS

Charlie Chaplin (*left*)
Einstein (*right*)

THE ARCHIVES, CALIFORNIA INSTITUTE OF TECHNOLOGY

Einstein (*left*) and William Campbell (*right*)

THE ARCHIVES, CAL. INST. OF TECHNOLOGY

1920s IN BERLIN, EINSTEIN HAD CLOSE contact with scientists such as Nobelists Walter Nernst, Max Planck, Robert Millikan, and Max von Laue (*above, left to right*). Einstein felt uncomfortable, despite a fine apartment and good working conditions (*below*). With the rise of the Nazis, Germany became dangerous for Jews, even ones as famous as Einstein.

ULLSTEIN - ULLSTEIN BILD

ULLSTEIN - ULLSTEIN BILD

tested. A British-led expedition to view a solar eclipse (in May 1919) sought to compare the positions of stars near the eclipsed Sun with the same star field minus the Sun.

If Einstein's theory was right, the stars' positions would change by a small amount. They did — and by almost exactly the amount predicted.

His theory stood confirmed — and Albert Einstein found himself a world celebrity overnight. This was the moment when Einstein became *Einstein*, popular shorthand for "incomprehensible genius."

As his fame grew, his personal life saw upheaval. In 1919, he and Mileva finally divorced — she had returned to Zurich with their two sons, Hans Albert and Eduard, in 1914. Soon after the divorce, Einstein married his cousin Elsa.

International celebrity

In 1921, he received the Nobel Prize in physics — although the award was for his discovery of the photoelectric effect, *not* relativity. But even if the Nobel committee had its doubts, few physicists did. During the 1920s and 1930s, physics underwent a wholesale revolution, pulling many younger figures into the field.

While Einstein did much to get the revolution going, as the years progressed, he found himself disagreeing more and more with the direction physics was taking. In particular, the rise of quantum mechanics, in which chance and statistics play central roles, was anathema to him. "Gott würfelt nicht," he growled — God doesn't gamble. The result, however, was that Einstein drifted away from the field's leading edge.

Outside of physics, Einstein was already a major figure in various social causes. Seeking to raise money for The Hebrew University of Jerusalem, he toured the United States in 1921 with pioneering Zionist Chaim Weitzmann.

He also joined a League of Nations committee on intellectual cooperation and was a leading member of the German League for Human Rights. He visited France, giving lectures on relativity, and sought to reestablish scientific and other ties broken by the war.

Yet if his theories were otherworldly, Einstein retained a streak of realism. Shortly after relativity was confirmed by the eclipse observations, he told the London *Times* newspaper, "Today in Germany I am called a German man of science and in England I am represented as a Swiss Jew. If I come to be regarded as a *bete noir* the description will be reversed, and I shall become a Swiss Jew for the Germans and a German man of science for the English." Later, he concluded a talk on relativity at the Sorbonne in similar terms.

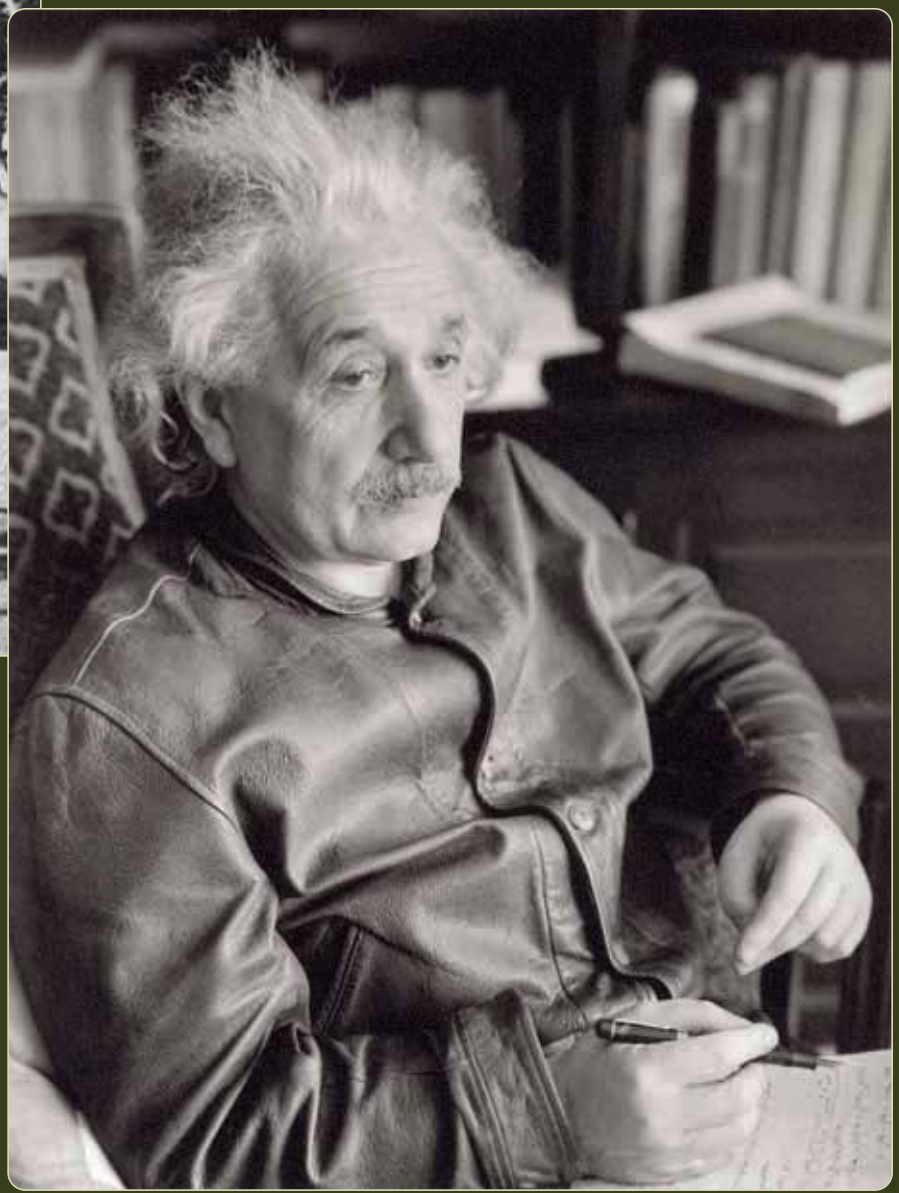
During the 1930s, totalitarian clouds gathered over Europe. Both fascism and communism sought to eradicate the individual in society in favor of the masses, and both sought to guide national economies by bureaucratic fiat.

Antiauthoritarian to the core, Einstein saw nothing good in these movements. Between 1930 and 1932, he made three trips to the United States, where he was appointed to the Institute for Advanced Study at Princeton University in 1932. He intended to divide his time between Berlin and Princeton, but the rise of Adolf Hitler and the Nazi Party to rule Germany in 1933 sent Einstein to America for good.

THE ARCHIVES, CALIFORNIA INSTITUTE OF TECHNOLOGY

THE ARCHIVES, CALIFORNIA INSTITUTE OF TECHNOLOGY

1930s EINSTEIN HAD NO TROUBLE relaxing and enjoying life as is evident in the famous image of him riding a bike (*top*) at the home of Ben Meyer in Santa Barbara, California. After moving to 112 Mercer St. in Princeton, Einstein devoted his time to physics research. He also was a popular speaker. On February 26, 1931, he spoke at the dedication of the Pasadena Junior College astronomy building (*above*).



LOTTE JACOBI COLLECTION, UNIVERSITY OF NEW HAMPSHIRE

1940s PROBLEMS OF WAR AND PEACE led Einstein in the late 1940s to advocate universal disarmament and a world government. Einstein joined J. Robert Oppenheimer (*below*), who had led the project to build the atomic bomb, in opposing any further development of atomic weapons. "The assertion that events abroad are forcing us to arm is incorrect. We must combat this false assumption with all our strength," Einstein said at Carnegie Hall, April 28, 1948.

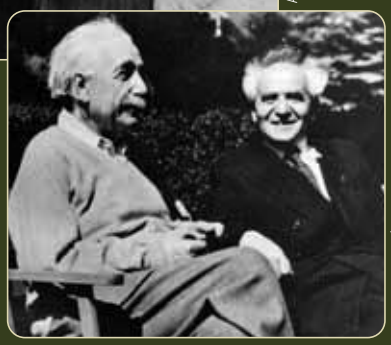
INTERNATIONAL NEWS PHOTOS/AP EMILIO SEGRÉ VISUAL ARCHIVES

1940 LIFE IN PRINCETON suited Einstein, who became a U.S. citizen in 1940, along with his secretary, Helen Dukas (*left*), and his stepdaughter, Margot (*right*).

Einstein (*left*) and J. Robert Oppenheimer (*right*)

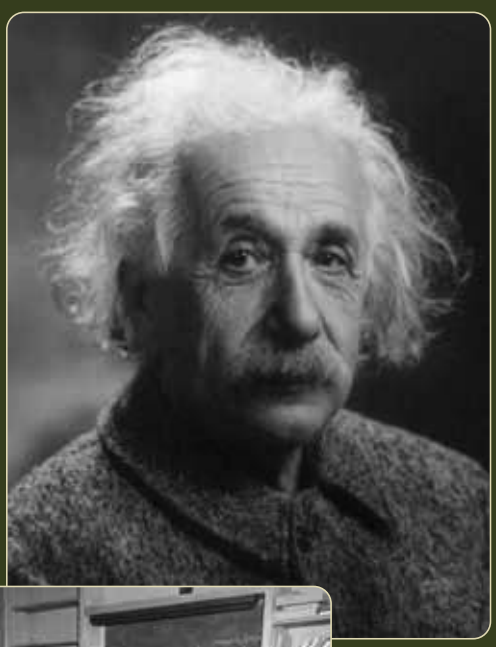
INTERNATIONAL COMMUNICATION AGENCY/AIP EMILIO SEGRÉ VISUAL ARCHIVES

AIP EMILIO SEGRÈ VISUAL ARCHIVES



AIP EMILIO SEGRÈ VISUAL ARCHIVES

1950s IN OLD AGE, Einstein lent his name to various causes and institutions, including Yeshiva University's school of medicine (*above*) in New York City. But he turned down an offer of the presidency of Israel, even when the offer came from its prime minister, David Ben-Gurion (*right*).



OREN JACK TURNER/LIBRARY OF CONGRESS, PRINTS & PHOTOGRAPHS DIVISION

ALAN RICHARDS/AIP EMILIO SEGRÈ VISUAL ARCHIVES

1955 EINSTEIN worked here. This is his office desk and blackboard as he left them when he died.

While at Princeton, Einstein continued his physics research, working with numerous young collaborators — in vain, as it proved — on a unified field theory linking general relativity to electromagnetism.

By 1939, the pacifist Einstein had become thoroughly alarmed by Germany's belligerence in Europe, and he was advocating military preparations to counter it. He signed a letter to U.S. President Franklin Roosevelt (drafted by another refugee physicist, Leo Szilard), urging the United States to undertake research on an atomic bomb based on uranium-fission reactions. The following year, Einstein became a U.S. citizen.

Once the United States entered World War II, Einstein did what he could to help the cause. He worked as a consultant for the U.S. Navy Bureau of Ordnance and also handwrote a copy of his 1905 paper on special relativity. It was auctioned for $6 million, and the proceeds went to the war effort. On the other hand, despite legends to the contrary, Einstein never worked on the Manhattan Project that developed the atomic bomb.

Like many people at the time, Einstein was horrified when advancing allied armies liberated the Nazi death camps, revealing the extent of the Holocaust — and he was likewise appalled by the atomic bombings of Hiroshima and Nagasaki. His response to both situations was to urge a world government and universal disarmament, and he joined or supported committees and organizations promoting these peaceful ends.

Some of these organization were suspected of being communist fronts, earning Einstein unwelcome attention from the FBI, which compiled a thousand-page dossier on him. During the Cold War, his pacifist and socialist ideas brought him more than once under suspicion of being a sympathizer with the Soviet Union.

Einstein remained active in Jewish organizations, and when Israel was founded in 1948, he was a strong supporter. But in 1952, when David Ben-Gurion, prime minister of Israel, invited him to become the second president of the Jewish state (following Weitzmann), Einstein refused.

Deeply moved, he said he was too old and too infirm, and all of his abilities and experience lay in dealing with objective matters. He said he knew a little about nature, but hardly anything about men. To the end, Einstein chose to remain first and foremost a physicist working on problems of physics.

By the 1950s, the startling theories of 1905 and 1916 had become deeply woven into the fabric of physics. Einstein had given birth to them, but they had long since become humankind's common possession — indeed, powerful forces shaping its future.

Albert Einstein, the man who remade the universe and gave humanity gifts it is still unsure how to use, slipped out of life as quietly as he entered it, dying in Princeton Hospital, April 18, 1955, at 76.

His last words went unrecorded; they were in German, and the nurse at his bedside did not speak the language. A

To hear Einstein talk about his most famous formula — you know the one — go to www.astronomy.com/toc

Relativity's infinit

If beauty is in the eye of the beholder, it's no wonder scientists leaped to embrace general relativity.

EINSTEIN SHOWED GRAVITY CAN TURN SPACE into a fun-house mirror. But it takes a lot of mass — such as that contained in galaxy cluster Abell 1689 — to make the distortions this obvious. Note how light from background galaxies has been twisted and smeared. NASA, ESA, AND THE ACS SCIENCE TEAM

e beauty

/// BY JAMES TREFIL

Relativity has always been the

odd man out in the sciences. In the general course of affairs, scientific ideas change slowly. Data challenging the old view starts to accumulate, then gets debated and worried about until, finally, kicking and screaming, scientists are dragged into a new way of looking at the world. With relativity, though, it was different. A young clerk in the Swiss patent office named Albert Einstein published a paper that

NEWTON AND EINSTEIN: MERCURY'S ODD MOTION

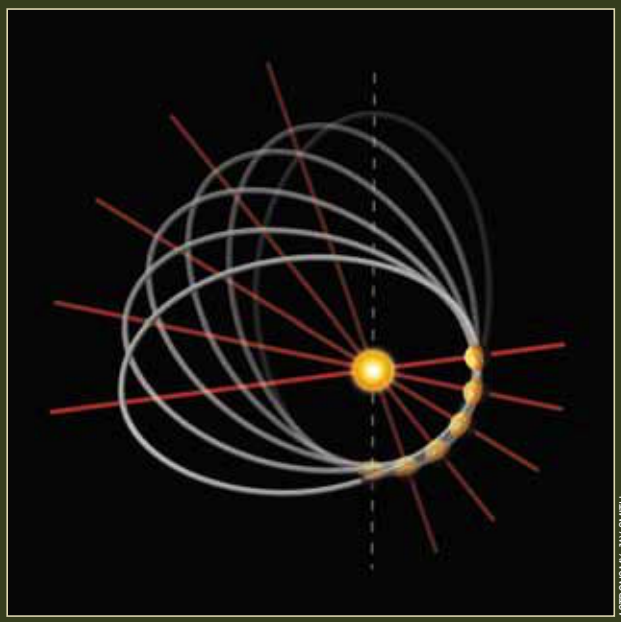
SIR GODFREY KNELLER

AIP/HEBREW UNIVERSITY/CALTECH ARCHIVES

ISAAC NEWTON AND ALBERT EINSTEIN developed the best descriptions of gravity. Newton's law of universal gravitation works in most cases where gravity is not too strong. It was all that was needed to send humans to the Moon and bring them home, and to launch the Voyager 2 spacecraft on a mission to four different planets, using gravity assists from each planet in turn to send it on its way.

Einstein's general relativity comes into play near strong gravitational fields. In the solar system, that means looking in the Sun's vicinity. Relativity's first test came from studies of Mercury's orbit. Newton calculated the inner planet's perihelion, or closest approach to the Sun, should advance about 531" per century. That's based on the gravitational influences from Venus (277"), Jupiter (153"), Earth (90"), and the other planets (10"). Yet Mercury's perihelion actually advances 574" per century.

According to Einstein, Mercury gets a tiny additional push because the force of gravity acting on it is slightly greater than Newton thought. The planet's high-speed orbital motion causes its "effective mass" to increase a little, an effect exacerbated because Mercury moves fastest near perihelion when the Sun's gravity is strongest. The result: an advance of perihelion 43" per century more than Newton predicted. — *Richard Talcott*



ASTRONOMY: JAY SMITH

THE PERIHELION OF MERCURY, the point in its orbit when it comes closest to the Sun, advances 574" per century, a bit more than Newton predicted but right in line with Einstein. The advance depicted here is exaggerated to show detail — each "orbit" illustrates how far Mercury's perihelion advances in 12,500 years.

was mainly about philosophy. When it appeared, scientists dispensed with their usual arguments about data and took the new ideas to heart.

A big reason for that reaction comes from the fact that relativity is beautiful. I know that seems a strange word to apply to what is, after all, a mass of equations, but that's the way physicists perceive it. The beauty stems from the central principle of Einstein's work called, appropriately enough, the principle of relativity. It says that any two observers, no matter where they are or how they are moving, will see the laws of nature operating the same way. The universe, in other words, doesn't care how it's being observed — it's the same for everybody.

Here's an example to help you think about this: A friend rides by in a car and, as he passes you, he throws a ball straight up in the air. To your friend in the car, the ball travels vertically up and then down. To you, the ball travels in an arc because the car moves while the ball glides through the air. The descriptions you and your friend give are different — each description is *relative* to the observer's location. On the other hand, if you each describe the laws of nature that made the ball do what it did from your point of view, you both would give the same answer, citing things like Newton's law of universal gravitation. Descriptions of events are relative to the observer — the laws of nature are not. (By the way, Einstein never liked the name theory of relativity for his brainchild. He wanted to call it the theory of invariants.)

Einstein worked out the consequences of this simple idea in two papers. In 1905, he published the results for the case where different observers are moving at constant (but different) speeds. This is called special relativity. Most of the strange things associated with relativity — moving clocks slowing down, moving objects getting more massive, and so on — come from this work. From a mathematical point of view, this is relatively simple stuff — the kind of material often taught to freshman physics majors.

Stepping on the gas

Extending the idea to all observers, even those who are accelerating, turned out to be a far more difficult proposition mathematically. The fact that it took Einstein — possibly the greatest mathematical physicist the world has known — until 1916 to straighten things out and publish this part of the theory should tell you all you need to know. The result of this work, called general relativity, remains our best theory of gravitation today.

So how does gravity get into it? Anyone who has felt heavier momentarily when an elevator starts climbing, or has been pushed back into the seat as a plane starts its takeoff, has experienced the answer. Einstein realized someone standing on a scale in an ascending elevator would see her weight increase, just as if the planet on which she was standing had suddenly grown more massive. To Einstein, this meant someone on Earth's surface feels the same force as someone in a

James Trefil *is the Clarence J. Robinson Professor of Physics at George Mason University. His latest book is* Human Nature: A Blueprint for Managing the Planet — by People, for People *(Henry Holt & Company).*

spaceship accelerating fast enough to produce an equivalent effect. As in special relativity, both people would see the same natural laws operating, except this time, gravity appears as just another effect of our choice of reference frame. This connection between frames of reference (like the accelerating elevator) and mass (which generates gravity) is the crux of general relativity. In Einstein's language, gravity becomes just an effect of geometry.

It's one thing to propose a theory like this, as beautiful as it may be, and something else to show that it makes predictions in line with experimental results. And here's where the anomaly I talked about earlier comes in. The Newtonian picture of the universe works extraordinarily well for most things we see. It was all scientists needed, for example, to guide the Cassini spacecraft to Saturn. The reason: Under most ordinary situations, the predictions of Newtonian gravity and Einstein's theory differ by so little that experiments can't differentiate between them. It's only in extreme situations — the vicinity of a black hole, for example, or the early stages of the Big Bang — that the two theories give really different results.

When physicists seek ways to validate Einstein's ideas — something that has to be done no matter how beautiful they are — we find surprisingly few possible tests. Until recently, in fact, there were only three. Although relativity passed these tests with flying colors, three experiments isn't a great foundation for what ranks as one of the most revolutionary ideas in modern science. Let's recap those classical tests.

Mercury on the loose

The first verification of general relativity wasn't so much a new test as an explanation of an old puzzle. For centuries, astronomers have known every planet orbits the Sun on an elliptical path. One point on each orbit, called perihelion, marks the planet's closest approach to the Sun. If only one planet circled the Sun, that point would be the same every time the planet came around its orbit. The gravitational pull of other planets, however, causes the point to move ahead a little each time the planet swings around. Astronomers call this effect the advance of the perihelion. It shows up most easily with Mercury, whose perihelion advances a little less than 600" (about one-sixth of a degree) per century — a small number by any measure.

When you account for everything that should affect the orbit of Mercury in the Newtonian picture, however, you come up about 43" per century short of explaining the planet's observed perihelion shift. Einstein pointed out that general relativity, which changes the force of gravity ever so slightly from its Newtonian form, could explain this tiny discrepancy. This was a triumph for the new theory. Since then, astronomers have used advanced radar-ranging techniques to measure accurately the perihelion shift of all the inner planets (including Earth), and the theory has come through each time. Score one for Einstein.

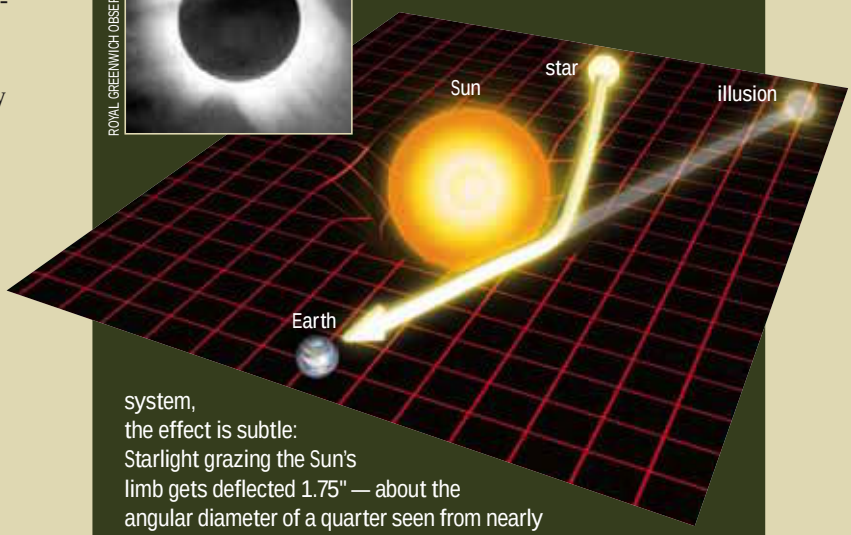
The most dramatic confirmation of general relativity occurred during the total solar eclipse of May 29, 1919. Einstein's theory predicts that when light passes near a

STARLIGHT'S LONG, STRANGE TRIP

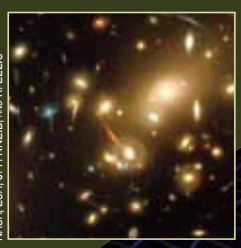
GEOMETRY RULES IN GENERAL RELATIVITY because the theory treats gravity as a manifestation of space-time curvature. Matter warps space-time, and whenever an object encounters that warpage, its path is deflected. That holds whether the object is a planet orbiting the Sun or a photon of light passing a massive object.

Observations of total solar eclipses provided an early test of general relativity. Scientists photographed the positions of stars near the Sun's limb during totality, and then compared them with the same star field on photos taken at night (when the Sun, obviously, wasn't nearby). Such observations began with the May 1919 eclipse (left) and continued for decades, confirming Einstein's prediction to about 10 percent. As in most relativity experiments made in the solar system, the effect is subtle: Starlight grazing the Sun's limb gets deflected 1.75" — about the angular diameter of a quarter seen from nearly 2 miles away.

ROYAL GREENWICH OBSERVATORY

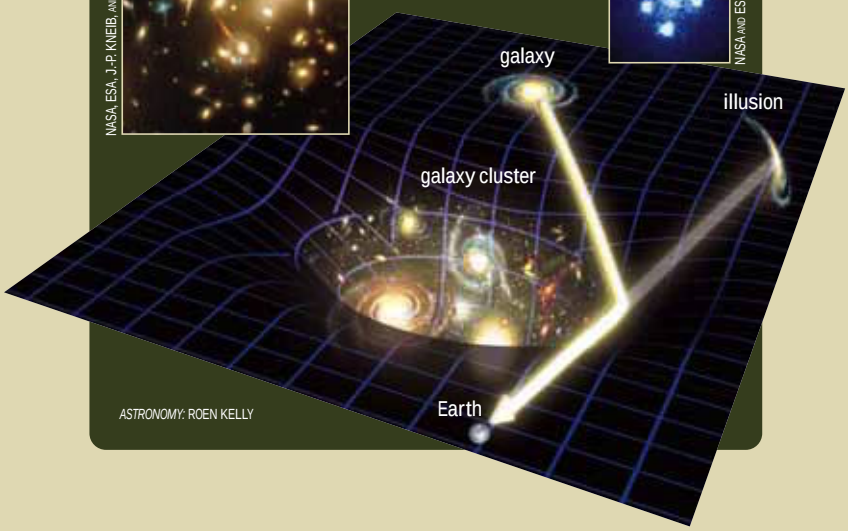


The Sun is only a middling star, however, and its ability to distort space-time is limited. If the deflecting body is a galaxy or galaxy cluster, the effect can be spectacular. In those cases, the body acts like a lens, magnifying and distorting the light of more distant objects. In the Einstein Cross (below right), a massive galaxy 400 million light-years from Earth creates four separate images of a single quasar located 8 billion light-years away. In the rich galaxy cluster Abell 2218 (left), the light from even more distant galaxies gets distorted into long, colorful arcs. — *R. T.*



NASA, ESA, J.-P. KNEIB, AND R. ELLIS

NASA AND ESA



ASTRONOMY: ROEN KELLY

WORKING HARD AGAINST GRAVITY'S CLUTCHES

ASTRONOMY: ROEN KELLY

GRAVITY AFFECTS LIGHT in many ways. The most famous effect is the deflection of starlight as it passes a massive object (see "Starlight's long, strange trip," page 49). But gravity produces another effect that changes the wavelength of light.

To understand gravitational redshift, it helps to use a technique Einstein often found useful: a thought experiment. Imagine an elevator with a laser on the floor and a detector on the ceiling. If the elevator floats freely in space, far from any gravitational field, and you shoot a laser beam from floor to ceiling, the detector should record the same wavelength of light as the laser emitted.

Now imagine you're in the same elevator but are free-falling in Earth's gravitational field. Between the time the laser emits light and it reaches the ceiling, the receiver approaches the source as the elevator accelerates downward. This should cause a Doppler shift to shorter, or bluer, wavelengths. Yet an observed blueshift would violate Einstein's belief that the laws of nature would be the same in both elevators. So, light moving upward against gravity has to be redshifted just enough to compensate for the Doppler shift that otherwise would appear.

The gravitational redshift has been seen in laboratories and in the Sun's light. But stronger gravity produces a greater effect. Light coming from Sirius B, a collapsed white dwarf star normally lost in the glare of brilliant Sirius (below), shows a redshift equivalent to the star moving away from Earth at 55 miles per second. — *R. T.*

JOHN CHUMACK

massive object like the Sun, its path bends. To an observer on the opposite side of the Sun, it would look as though the light were coming from a slightly different direction and, therefore, the position of the object had shifted.

Most of the time starlight passes near the Sun, the Sun's brilliance overwhelms it. During a total solar eclipse, however, the Moon blocks the brightest part of the Sun from view, so light from distant stars passing near the solar surface can be detected. To test general relativity's prediction, 6 months before the 1919 eclipse, astronomers photographed the star field destined to lie on the edge of the eclipsed Sun. The stars were high in the night sky and easy to see. During the eclipse, scientists shot the same star field and checked the apparent star positions.

British astronomer Sir Arthur Eddington led one eclipse expedition to Príncipe Island off the coast of Africa. When he announced the stars' positions matched Einstein's predictions, the scientific community, who wanted to believe the theory anyway, jumped on the general-relativity bandwagon. Today, radio astronomers routinely record radio waves from distant quasars as the waves skim the Sun's surface, and the measured displacement of the waves always matches the theory's predictions. Score two for Einstein.

Another phenomenon associated with Eddington's measurement, however, has puzzled me (and many other scientists): the almost instantaneous elevation of Einstein to a major figure in pop culture. Characters modeled after Einstein — kindly, pipe-smoking, white-haired scientists — routinely appeared in movies from the 1920s to 1950s. Even today, a half century after Einstein's death, you can walk into a college bookstore and see him on posters, right next to other icons of the mid-20th century like Marilyn Monroe and James Dean. Understanding why this happened constitutes, in my mind at least, a question in the social sciences nearly as profound as the questions physicists ask about the nature of gravity.

Out of a gravity well

The third classical test of relativity came from the theory's prediction that light moving upward in a gravitational field (think of a flashlight beam directed into the night sky) would have its wavelength shifted slightly to the red. In essence, the light loses energy as it climbs out of the field. One of the early applications of laser technology was to verify this prediction in 1959. Astronomers also have helped verify the gravitational redshift, although not as precisely as laboratory experiments. Light climbing out of a star's gravitational field should be redshifted more than in the laboratory. For the Sun, the effect amounts to an increase in wavelength of less than two parts per million. But with the much stronger gravity at a white dwarf's surface, the effect is nearly 50 times larger. Observations of white dwarfs show the redshift matches Einstein's predictions to within about 20 percent.

So there you have it. Until the 1980s, this was all general relativity had to hang its hat on. It's a surprisingly thin list for such a powerful new idea.

The last couple of decades have seen a flood of new tests: some completed, some proposed, and some ongoing. It's not

that modern scientists have improved on the theory or performed new calculations. It's just that, as so often happens in the history of science, a lot of ordinary lab work gradually has improved our ability to measure things. Tests beyond our reach a few decades ago now can be done, or at least contemplated. Look at it this way: If both Newton's and Einstein's predictions about a certain number are identical for seven decimal places; if you can measure that quantity to eight decimal places, you can see which theory is right. Basically, that's how scientists have tried to verify general relativity during the past 2 decades.

Scientists recognize three broad classes of general-relativity tests. Some are straightforward attempts to confirm predictions of the theory — "Relativity says X will happen, so let's measure X." Another class begins with a prediction of some effect but is motivated more by the desire to discover new things about the universe. In this case, relativity is just a side issue. Finally, and most interesting to me, comes the class of experiments in which tests of general relativity are inadvertent. The theory gets tested, but only in the context of some larger engineering endeavor.

Probing gravity

Last April, an extraordinary event in the history of general relativity took place when an experiment called Gravity Probe B was launched from Vandenberg Air Force Base, California. I call this event extraordinary for several reasons, not the least of which is that scientists prepared for it longer than any scientific experiment I know.

When I was a graduate student at Stanford University in the 1960s, I met a young English postdoctoral fellow named Francis Everitt. Sporting a fashionable '60s ponytail, he was planning a major test of general relativity. Today, the ponytail is gray, the postdoc is a senior professor, and the experiment is finally operating.

The easiest way to think about Gravity Probe B is to picture an ordinary toy top. The top spins around its axis, but the axis also executes a lazy circle. The forces exerted on the top's point by the floor coupled with gravity cause the latter effect, known as precession. Most spinning objects show precession. Earth's axis, for example, goes through one precessional cycle every 26,000 years, caused by the gravitational tugs of other solar system bodies acting on Earth's equatorial bulge.

The Gravity Probe B experiment employs the world's four most-precise gyroscopes (think of them as high-tech tops) mounted in a satellite, with the aim of measuring their precession. General relativity predicts a small precession due to Earth's gravitational effects and the satellite's orbital motion. It's taken a long time for Gravity Probe B to fly because scientists had to overcome a number of technical hurdles for such a precision experiment to work, not to mention putting it into a rocket's nose cone and shooting it into space.

The gyroscopes — spinning 400 miles (640 kilometers) above Earth as you read this — are spheres made so precisely they have been called the world's roundest objects. Blow up the ping-pong-ball-size quartz spheres to the size of Earth, and the tallest "mountain" would be less than 3 feet high.

EINSTEIN LOOKS TO THE COSMOS

$$R_{\mu\nu} - \tfrac{1}{2}g_{\mu\nu}R = 8\pi T_{\mu\nu} - \Lambda g_{\mu\nu}$$

EINSTEIN'S FIELD EQUATION may look simple (above), but enter at your own risk. The basis for general relativity, the field equation includes mathematical expressions known as tensors. The equation tells how matter and energy (represented by the stress-energy tensor, $T_{\mu\nu}$) warps space-time (represented by the metric tensor, $g_{\mu\nu}$).

The innocuous looking Λ in the last term is Einstein's famous cosmological constant. The permanence of the universe was a firm belief in Western philosophy when Einstein developed relativity, and he was unwilling to give it up. When the original field equation told him the cosmos must be evolving, he modified the equation to keep the universe static. When he learned the universe *is* expanding, he called the cosmological constant "my greatest blunder."

But perhaps he was too hasty again. Observations of distant supernovae now show the expansion of the universe is accelerating. A cosmological constant could be one explanation. If so, this could be a rare instance when two wrongs do make a right.

General relativity quickly became the tool cosmologists used to study the universe. The first new cosmological model came in 1917 from Dutch astronomer Willem de Sitter. In the 1920s, both Russian mathematician Alexander Friedmann and Belgian astronomer Georges Lemaître developed other models. Lemaître first hypothesized the universe might have begun with a Big Bang.

General relativity also provides the foundation for black holes — objects with gravity so strong not even light can escape. In 1939, American physicists Robert Oppenheimer and Hartland Snyder published the first description of black holes based on relativity. At the time, most scientists (including Einstein) didn't think these beasts existed. But they do: Astronomers find them in binary systems, where a stellar-mass black hole swallows gas from its companion (below); and in active galaxies and quasars, where supermassive black holes drive the most energetic objects in the universe. — *R. T.*

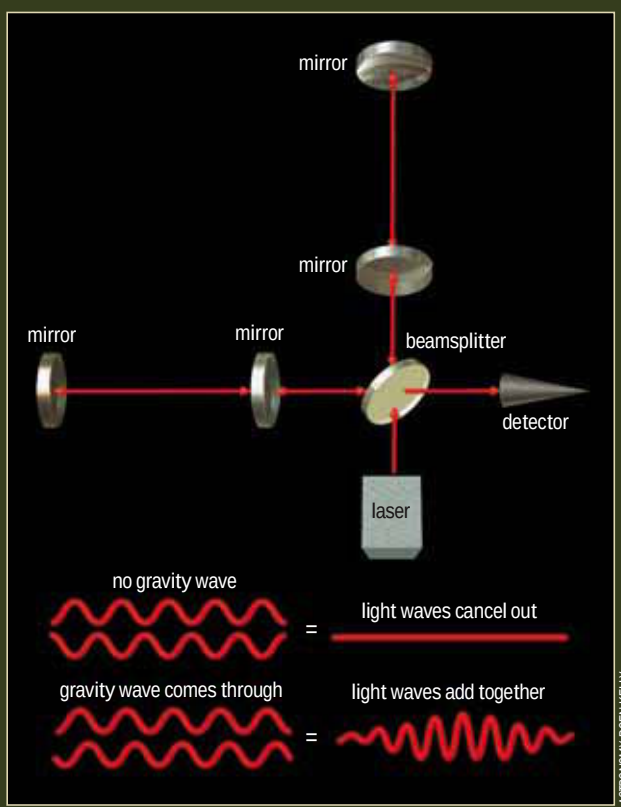
ESA, NASA, AND FELIX MIRABEL

CATCHING THE PERFECT WAVE

LIGO LABORATORY

IF THE SUN CEASED TO EXIST this instant, it would take 8 minutes for the sky to darken — the length of time it takes light to reach Earth from the Sun. Would we fly off into space before then? No. Special relativity says information can't travel faster than the speed of light. We'd remain blissfully unaware for the same 8 minutes.

Although mundane events like the Sun's death create ripples in the fabric of space-time, general relativity tells us bigger events — like a supernova or the collision of two black holes — trigger greater disturbances. Those are the kinds of events LIGO is searching for (see "Riding a wave" at right). But scientists already have detected gravitational waves indirectly. Observations of a binary pulsar, in which two neutron stars orbit each other, show the system loses energy by radiating gravitational waves at just the rate relativity predicts. Americans Russell Hulse and Joseph Taylor won the 1993 Nobel Prize in physics for their study of the binary pulsar. — *R. T.*



ASTRONOMY: ROEN KELLY

THE LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY consists of two sites, one in Hanford, Washington, (seen at top) and one in Livingston, Louisiana. Both have L-shape arms measuring 2.5 miles long that house the lasers and mirrored test masses needed to detect gravitational waves.

Scientists estimate that, in 2 years, we'll know whether general relativity has passed this test.

Relativity also predicts that when a massive object moves, it creates waves in space, much as your hand creates waves when you move it through water. These so-called gravitational waves are weak, but general relativity says they ought to be there. And just as waves on the water make a cork bob up and down, gravitational waves stretch and distort massive objects. A gravitational wave hitting a basketball, for example, will stretch it sideways, let it snap back, then stretch it up and down, before letting it go back to its original configuration. This stretch is small — a gravitational wave hitting your car, for example, will distort its shape by about the length of the nucleus of a single atom. Scientists have long tried, unsuccessfully, to detect these waves using ever-more-refined apparatus.

Riding a wave

Enter LIGO: the Laser Interferometer Gravitational-Wave Observatory. This mammoth project uses equipment at two separate sites, one in Louisiana and one in Washington state, to try to detect the presence of gravitational waves. LIGO construction was finished in 1999 and initial operations began in 2001; currently, the observatory is close to reaching its design sensitivity.

At the heart of each installation is a huge L-shape vacuum pipe; each arm of the L is 2.5 miles (4 km) long. A test mass outfitted with mirrors at the end of each arm is free to move in response to passing gravitational waves. Think of them as two pieces on the surface of a "basketball" 2.5 miles in diameter. Laser beams running through the vacuum pipe precisely monitor the positions of the masses, which will move far less than the diameter of a single atom when a wave passes. Two installations provide a check against a local disturbance — micro-earthquakes or other sudden vibrations, for example, or fluctuations in the lasers themselves — being mistaken for a gravitational wave.

While LIGO was built to detect the gravitational waves predicted by general relativity, its real purpose is to open a new window on the universe. If LIGO detects gravitational waves that are somehow different from what general relativity predicts, it still will be a success. It will bring us new information about the universe, just as the first radio telescopes did in the 1930s.

Walk into any electronics store, and you can buy your own apparatus to test general relativity. The Global Positioning System (GPS) is an example of what I call an inadvertent test of the theory. The system's main working parts are 24 satellites, each containing a precision atomic clock, orbiting about 14,500 miles (23,300 km) above Earth. By measuring how long it takes signals to travel from several satellites to your location, a GPS receiver calculates your exact location.

Relativity comes into this technology in two places. Because the satellites move briskly in their orbits, their atomic clocks slow down. This is an effect purely of special relativity. In addition, because the satellites orbit so far above Earth, they lie in a different gravitational field than the surface. In this situation, general relativity predicts the clocks

should speed up because of the lower gravity in orbit. This effect is complicated by the fact that the satellites move toward and away from Earth as they orbit. The system has to correct for all of these effects to produce an accurate position.

I've been told that when the first satellites in the GPS system were built, the engineers so distrusted the unfamiliar effects of relativity, they put in a switch that would allow them to turn the relativistic corrections off if they had to. Needless to say, the switches were never used.

The atomic clocks in the GPS satellites are accurate to 13 decimal places, and you need every one of those decimal places to make the system work. Were the effects of relativity ignored, there would be a cumulative error of about 7 miles (11 km) per day in the position of each satellite in the system. This means every time you turn on your GPS receiver, you perform your own test of the theory, whether you mean to or not.

Back to the future

Even if general relativity meets all the current tests — as most physicists expect it will — that isn't the end of the story. We know the theory has to break down at some point, if only because, in its present form, it does not incorporate the effects of quantum mechanics. (Quantum mechanics describes the universe at tiny scales — it's how physicists understand the behavior of atoms.)

There are other ways general relativity could fail, and scientists are thinking about testing many of them. One intriguing way relativity could falter would be a violation in a basic symmetry built into the theory. Relativity predicts, for example, that rotating a clock in space will not change the rate at which it ticks. If this is false, the concepts of space and time built into the theory would have to change. This is precisely what happens in some theories that attempt to combine quantum mechanics and general relativity.

Whether or not clocks actually speed up or slow down in this way can be tested by watching two neighboring clocks as Earth's rotation changes their positions relative to each other. Experiments at the Harvard-Smithsonian Center for Astrophysics already have shown that, for some clocks, relativity can be trusted out to 31 decimal places. Nevertheless, scientists are planning to run experiments on the International Space Station to compare the rate at which different clocks tick. As the station moves around in its orbit and rotates around its axis, the relative positions of the clocks will change rapidly. If relativity is violated, we should see them go into and out of sync with each other.

So that's where relativity stands on the brink of its second century. Thanks to the ingenuity of modern experimenters, general relativity no longer sits in lonely splendor as the only poorly tested major theory in science. From now on, it will have to take part in the rough-and-tumble of skeptical experiments. This, of course, is only fitting because that is the lot of every other scientific theory — whether it was devised by Einstein or not. A

To learn how your computer can look for gravitational waves while you sleep, see www.astronomy.com/toc

START DRAGGIN' MY FRAME AROUND

GRAVITY PROBE B, STANFORD UNIVERSITY

EARTH IS NOWHERE NEAR AS BIG as the Sun and warps space-time much less. Still, Earth creates a small dimple in the space-time fabric. General relativity predicts that, as Earth rotates, it should twist the local fabric by a minuscule amount. Derived in 1918 by Austrian physicists Joseph Lense and Hans Thirring, this is known as the Lense-Thirring effect or, more colloquially, frame dragging. This is what Gravity Probe B and its precision gyroscopes are looking for.

Frame dragging should affect any Earth-orbiting satellite. Last year, researchers Ignazio Ciufolini of the University of Lecce, Italy, and Erricos Pavlis of the Joint Center for Earth Systems Technology in Baltimore announced they had detected frame dragging. They studied the orbits of NASA's Laser Geodynamics Satellite (LAGEOS) and the joint NASA/Italian Space Agency LAGEOS II and found that the plane of the orbits shifted about 6 feet (2 meters) per year — within 1 percent of what relativity predicts. Ciufolini and Pavlis estimate their measurement is accurate to 10 percent. Gravity Probe B should whittle that down to less than 1 percent. — *R. T.*

RUSS. LEESE, GRAVITY PROBE B, STANFORD UNIV.; INSET: KATHERINE STEPHENSON, STANFORD, LOCKHEED MARTIN

GRAVITY PROBE B'S number 4 gyro is inspected by Stanford University engineer Chris Gray in August 2000 (above). The spacecraft (inset) was launched in April 2004. A poster of Albert Einstein (top) appears shrunken and flipped as its image passes through one of Gravity Probe B's clear, uncoated quartz rotors.

BY MARTIN RATCLIFFE AND ALISTER LING

FEBRUARY 05

Although Saturn remains the standout target in the evening sky, Comet Machholz makes a strong challenge, glowing bright enough to be seen with the naked eye.

A comet's tail of gas and dust

Visible to the naked eye under a dark sky, the latest in a year-long string of nice comets couldn't be placed better for observers in the Northern Hemisphere. Comet C/2004 Q2 (Machholz) can be found high in the northern sky throughout February as it slides slowly down toward the North Star, Polaris. It should glow around 5th magnitude, a bit fainter than the Beehive star cluster (M44) now rising in the east. You'll need binoculars to see it from the city.

Like a pop fly in baseball rounding the top of its arc, Machholz appears to slow this month. From Earth's perspective, it lies almost straight up from the north pole, giving us a good line of sight to its tail, which points away from the Sun. You should see two tails. A slightly bluish tail of ionized gas blowing straight out in the solar wind of charged particles, and a yellow-white tail arcing gracefully as ejected motes of dust begin tracing their own orbital arcs. The comet's tails should become easier to see this month because they are leaving the brighter background of the Milky Way in Perseus and Cassiopeia.

Saturn and its glorious rings dominate the evening sky. Look for the bright, steady, pale-yellow "star" halfway up in the east as the sky grows dark. If Earth's atmosphere is not too turbulent, crank up the magnification to take a close look at the shadow of the planet on the rings. The shadow is now on the opposite side from where it was a couple of months ago and growing wider week by week, the same way your shadow gets longer in the afternoon.

STATELY ORION, with its brilliant blue stars and ruddy Betelgeuse, climbs into the evening sky, a sure sign of winter's hold on Earth. JERRY SCHAD

Planetary enthusiasts have kept giant Jupiter and its enticing cloud features under scrutiny ever since it returned to view last October. Now that the planet rises before midnight, thousands more observers will join in. Will the Great Red Spot finally begin a comeback to recapture its name? Are there any new white ovals? Backyard observers return to Jupiter every year because it always shows plenty of detail, but the unexpected remains one of the planet's strongest drawing cards.

Although the Moon lies much closer to Earth than Jupiter, perspective makes it appear to have a close encounter with the planet the morning of January 31. Jupiter lies about two to three lunar diameters from the Moon in the 2-o'clock position relative to the lunar terminator.

What happens when the Moon passes in front of a red supergiant star? On the morning of February 4, around 5h Universal Time, those in southern Scandinavia and Eastern Europe will find out as the Moon hides Antares. Next month, and in May, observers in North America have the chance to see beautiful dark-sky occultations of Antares.

Most stars appear as mere pinpoints through a telescope. Yet bloated red supergiants like Antares are so huge that when the knife edge of the Moon cuts across them, they disappear in the blink of an eye instead of instantaneously. That may not sound much slower, but it is noticeable.

A delicate, thin crescent Moon returns to the evening sky February 9. Sighting this young Moon, just 1 day old, should mark a personal best for most newcomers. The next evening, the crescent appears higher and more visually appealing, with the Moon's dark face lit by earthshine.

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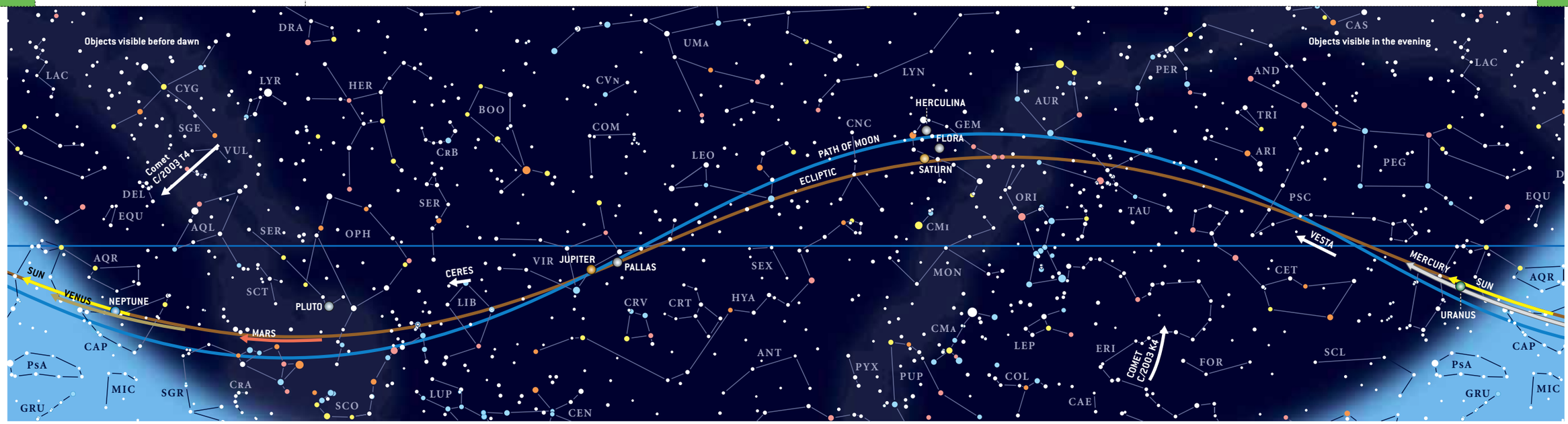
Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



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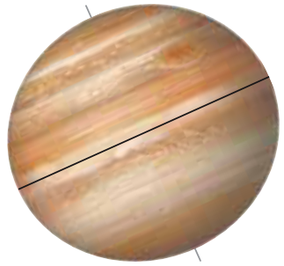
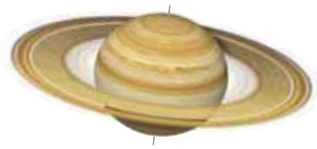
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

[28] [27] [26] [25] [24] [23] [22] [21] [20] [19] [18] [17] [16] [15] [14] [13] [12] [11] [10] [09]

PLANETS	MERCURY	MERCURY	VENUS	MARS
Date	February 1	February 28	February 15	February 15
Magnitude	–0.9	–1.5	–3.8	1.3
Angular Size	4.8"	5.5"	10.0"	4.8"
Illumination	97%	90%	98%	93%
Distance (AU) from Earth	1.397	1.231	1.673	1.933
Distance (AU) from Sun	0.456	0.327	0.728	1.512
Right Ascension (2000.0)	20h22.1m	23h27.7m	21h12.7m	18h25.2m
Declination (2000.0)	–21°20'	–4°11'	–17°12'	–23°43'

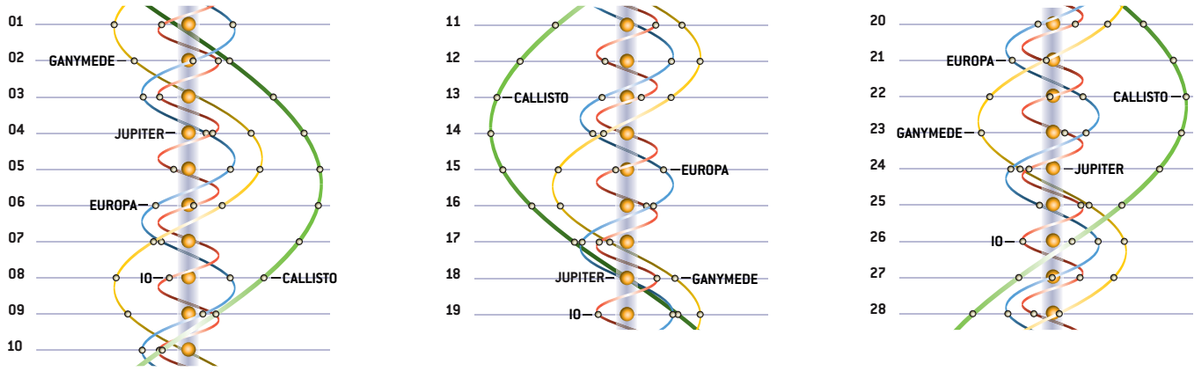


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
February 15	February 15	February 15	February 15	February 15
–2.3	–0.2	5.9	8.0	13.9
41.1"	20.2"	3.4"	2.2"	0.1"
99%	100%	100%	100%	100%
4.794	8.235	21.033	31.034	31.353
5.456	9.063	20.061	30.065	30.912
13h10.6m	7h32.6m	22h32.6m	21h11.7m	17h35.4m
–5°53'	21°48'	–9°57'	–16°18'	–15°13'



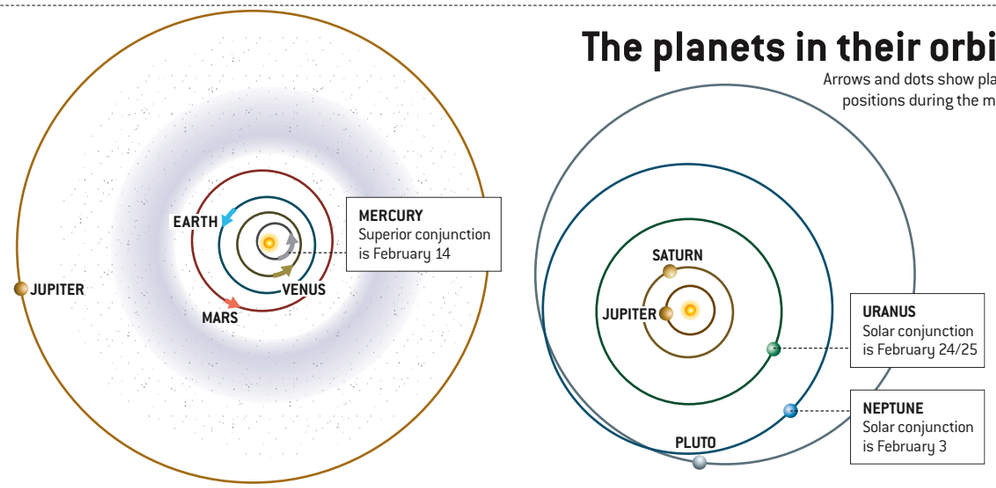
Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EST on date shown. South is at top to match the view in a telescope.



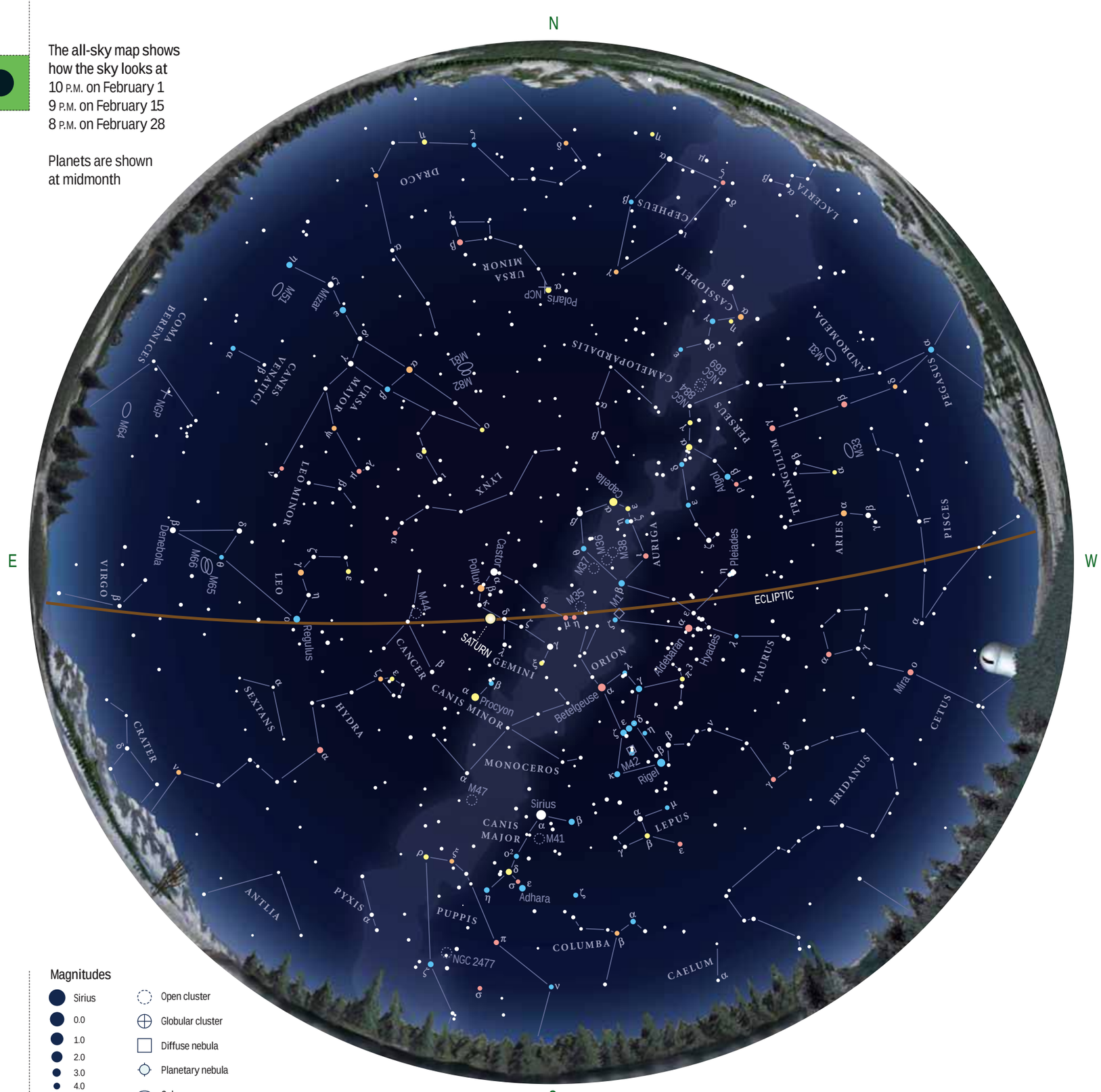
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
10 P.M. on February 1
9 P.M. on February 15
8 P.M. on February 28

Planets are shown at midmonth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PEGASUS
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M82
NGC 884
NGC 869
PERSEUS
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TRIANGULUM
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Capella
AURIGA
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M37
M35
M1
Pleiades
ARIES
PISCES
ECLIPTIC
Aldebaran
Hyades
TAURUS
Mira
CETUS
ERIDANUS
Castor
Pollux
M44
SATURN
GEMINI
CANCER
ORION
Betelgeuse
Procyon
CANIS MINOR
HYDRA
SEXTANS
CRATER
MONOCEROS
Rigel
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M47
Sirius
M41
CANIS MAJOR
LEPUS
Adhara
PUPPIS
PYXIS
ANTLIA
COLUMBA
CAELUM
NGC 2477
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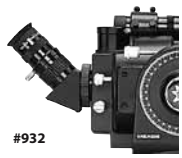

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- Double the eyepiece power
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** Individual filters may be purchased separately for* ***$14.95***

Series 4000 Moon Filter

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- Threads into 1.25" barrels

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- Narrowband filters yield spectacular high contrast views of faint nebulae, and work in heavily light-polluted conditions

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- Isolate the 496nm and 501nm O-III lines

#908X

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THE DEEP SKY

Clouds of gas and dust permeate the Milky Way. A small region of Perseus allows you to follow the connections among emission, reflection, and dark nebulae.

By the starry light

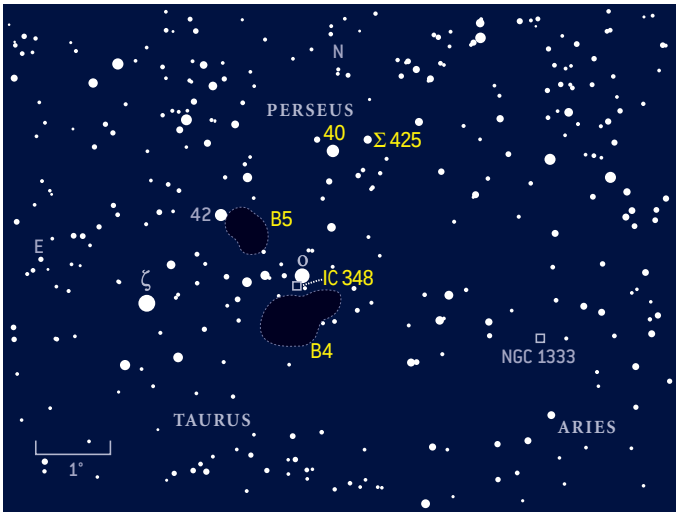
Last month, we examined the California Nebula (NGC 1499) in Perseus, a classic example of an emission nebula. A hot, massive star floods space with ultraviolet light, which strips electrons from atoms. When these so-called ionized atoms settle down from this excited state, many emit light in the visible part of the spectrum.

But what if the star isn't that hot? Its light still can scatter off the gas atoms and dust, in much the same way light scatters off a fog bank on Earth. The most famous reflection nebulae are the wisps surrounding the Pleiades star cluster in Taurus and the wonderful blue and yellow clouds around Rho Ophiuchi near Antares.

Martin Ratcliffe *is former president of the International Planetarium Society.* Alister Ling *is a meteorologist for Environment Canada.*

Another interesting, if less well-known case, lies in Perseus. IC 348 resides just south of 4th-magnitude Omicron (o) Persei. The nebula appears as an ill-defined circular patch of light surrounding a pair of stars. About a dozen stars clump around these two, probable remnants of a communal star cluster formed from the cloud. With a diameter of 6', the brightest patch of IC 348 is relatively small, similar in apparent size to the bright galaxies of the Virgo cluster, so it's okay to bump up the power to get a good look.

IC 348's low contrast makes it most appropriate for dark-sky viewing. One trick to try: Move the scope south or southeast to put the bright stars just outside the field of view. Let your eye readjust, then come back slowly toward the nebula. If conditions are right, you'll see the background has a faint, milky glow on it.



THE IC 348 EMISSION NEBULA in Perseus lies just south (above) of the bright star Omicron Persei. DIGITIZED SKY SURVEY

A lake of blackness

You might think if no star lies near or shines bright enough to light up the dust and gas, the interstellar medium would be transparent. Not so. Instead, like clouds backlit in deep twilight, interstellar clouds absorb light from beyond. If they contain enough stuff, visible light can't get through.

Swing your telescope 1° northeast of IC 348, and you'll see all the faint stars have disappeared. This is B5, cataloged by pioneering astronomer E. E. Barnard with his wide-angle photographs of the Milky Way. You may need to use medium power (100x) to pull in the fainter stars on B5's periphery to make the nebula stand out a bit more.

Slew your scope back through Omicron, and you'll dip into another dark expanse, B4. Keep moving your scope around, trying to follow the path of obscuration. If you continue west, you might run into NGC 1333, a modestly bright reflection nebula.

Doubling up

A couple degrees north of the IC 348 complex lies the double star 40 Persei. This very uneven pair sports components glowing at 5th and 10th magnitude. They serve as a departure point to another double, Σ425, which makes a nice test object for a 4-inch scope. Both stars glow at magnitude 7.6 with a mere 1.8" separation, half the gap of summer's famous Double Double in Lyra. For the best view in small instruments, pump up the power to 50x per inch of aperture.

THE PLANETS

Saturn continues its conspicuous apparition these February evenings, while the morning sky offers brilliant Jupiter and Mars passing several bright deep-sky objects.

Saturn dominates the eastern sky February evenings — it is the only planet on fine view until midnight approaches. This news-making planet has everything going for it to be the star of the nightly show: Its magnificent rings show up beautifully through any telescope, as do its intriguing moons, and the Cassini spacecraft currently flies among the worlds of the saturnian system. Jupiter joins the sky action shortly before midnight, while Mars comes into view in the southeast as dawn approaches.

The solar system's fleeting innermost planet makes a brief appearance in the evening sky in the final days of February, but **Mercury** will put on a much better show in March. On February 28, it shines at magnitude –1.5 and stands 5° above the western horizon 30 minutes after sunset. You will need an exceptionally clear horizon to spot the planet when it lies this low, and binoculars certainly will help the quest. Its visibility improves in early March, when a crescent Moon skims by.

Saturn proves easy to pick out of the darkening eastern sky during February. It shines at magnitude –0.3 early in the month and fades slowly to magnitude –0.1 by month's end, yet it still easily outshines neighboring Castor and Pollux. These two stars are the luminaries of Gemini the Twins and stand to the upper left of Saturn in the evening. This trio of bright objects lies directly to the left of the majestic constellation Orion as they climb the eastern sky.

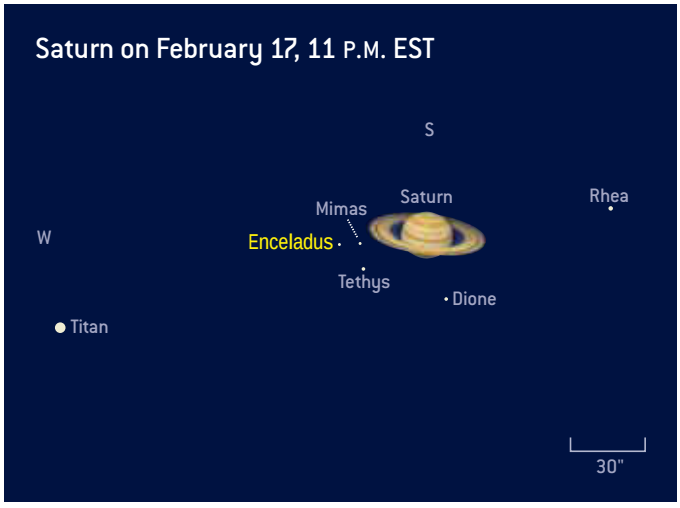
While Earth's nightly rotation carries Saturn to the west, the combined motions of Earth and Saturn in their orbits currently causes Saturn to move west relative to the background stars, the reverse of its normal easterly motion. Saturn passed opposition in January and, consequently, Earth now is overtaking the ringed planet.

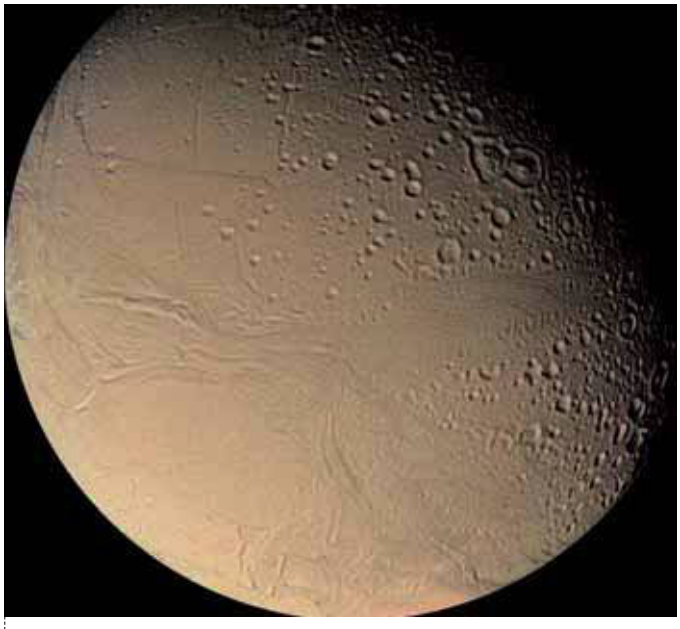
During February, Saturn lies an average distance of 8.2 astronomical units, or 760 million miles, from Earth. Saturn's 75,000-mile-wide disk reaches 20" across when viewed from here, and its ring system spans 46" at its widest.

Telescope owners have plenty of tempting targets this month. The brightest of Saturn's retinue of 37 moons — at last count — shows up easily: Titan could be spotted with binoculars if Saturn weren't so close. Keen eyes still might succeed at this feat when Titan lies at greatest elongation east or west of the planet. On February 3 (west), 11 (east), 19 (west), and 27 (east), Titan lies just under 4' from the center of the ringed planet. Try spying the moon with binoculars mounted on a steady tripod.

Through a telescope, you can track Titan easily throughout its whole 16-day orbit of Saturn. The moon passes north of Saturn February 15 and south both February 7 and 23. Even a low-power eyepiece can pick up this moon.

Higher magnification allows you to spot some of the moons closer to Saturn. Using a higher power reduces the glare from Saturn by spreading its light over a larger area. Mimas scampers around the planet in just 1 day and glows at magnitude 12.9. Enceladus completes





SATURN'S MOON ENCELADUS receives its first visit from the Cassini spacecraft this month. Planetary scientists hope to unravel the complex geology revealed by Voyager more than 2 decades ago. NASA/JPL

an orbit every 1.4 days and glows at magnitude 11.7. Cassini makes its first close approach to Enceladus February 16/17. Images taken by the Voyager spacecraft revealed intriguing geological features on this moon, so planetary scientists eagerly await the first close-ups from Cassini's more-powerful camera.

A trio of 10th-magnitude moons awaits your discovery between the orbits of Enceladus and Titan. Tethys takes 1.9 days to circle Saturn, Dione 2.7 days, and Rhea 4.5 days.

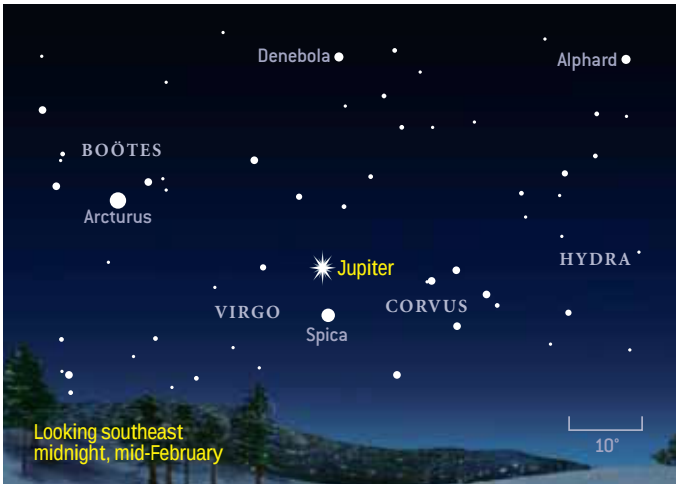
Outside Titan's orbit lies Hyperion, Iapetus, and Phoebe, although Iapetus is the only one visible through a small scope. Its curious nature — bright material covers half the moon, and dark material coats the other half — causes it to vary in brightness by 5 times as it orbits Saturn. You'll find it fading during February as it moves from western elongation to east of the planet.

Jupiter rises around 11 p.m. January 31, and an hour later, the Last Quarter Moon joins it, standing 12° below. A waning gibbous Moon passes 2° south of Jupiter the morning of February 27.

The giant planet remains in the constellation Virgo the Maiden. On February 19, it appears 0.2° south of the 4.4-magnitude star Theta (θ) Virginis. Jupiter itself shines hundreds of times brighter, at magnitude –2.3, just 0.2 magnitude fainter than it will be at opposition in early April.

Jupiter's appearance through a telescope reveals a disk 41" across, almost as wide as Saturn's rings viewed through the same scope. Its brilliant disk can hide some low-contrast atmospheric features, as can a poorly collimated Newtonian or Cassegrain telescope. The best views always come when your telescope is well-collimated — and when the tube has settled to the outside air temperature. With these precautions, your planetary viewing will take on added interest.

Jupiter's atmosphere shows dynamic changes and rotates at two different speeds. The equatorial region completes one full rotation in 9 hours and 50 minutes, while higher latitudes take about 5 minutes longer. The churning that results creates plumes of material around the outer edges of the two dark equatorial belts.



THE TRIFID AND LAGOON NEBULAE (top and bottom, respectively) host Mars February 7, when the planet passes between them. VINCE FARNSWORTH

Jupiter's four Galilean moons — Io, Europa, Ganymede, and Callisto — can be seen easily through any telescope. Indeed, Galileo first spotted these worlds orbiting Jupiter back in 1610. Each night, you'll notice the moons in different positions relative to Jupiter. Often one or two, and rarely three, disappear behind or in front of Jupiter. Such occultations and transits are fascinating to watch, especially when a moon's shadow falls as a jet-black dot on the jovian atmosphere during a transit.

You'll have to wait until almost 5 a.m. to see another planet appear. Mars climbs above the southeastern horizon in the company of the stars of Sagittarius at 4:40 a.m. local time February 1 and half an hour earlier by the 28th. The Red Planet is far from spectacular through a telescope now, but it will be later this year. It currently lies 180 million miles from Earth. The tiny globe spans a mere 5" and shines at magnitude 1.3.

The morning of February 5, you'll find Mars 5° above a thin crescent Moon. Although Mars won't reveal much surface detail this month, it passes near a few nice deep-sky objects in the richest part of the Milky Way. Mars slides between the Lagoon and Trifid nebulae (M8 and M20, respectively) the morning of February 7. Try to catch the trio early, before the fast-approaching twilight washes out the nebulae. On February 18, Mars lies 0.3° north of the globular cluster M22, making a fine photo opportunity for rich-field telescopes. By month's end, Mars stands east of the handle of the Teapot asterism in Sagittarius.

METEORS AND MOONS

On February 15, Earth's Moon passes just south of the most conspicuous star cluster in the sky. Coincidentally, the following night is the best time to spy two prominent lunar peaks.

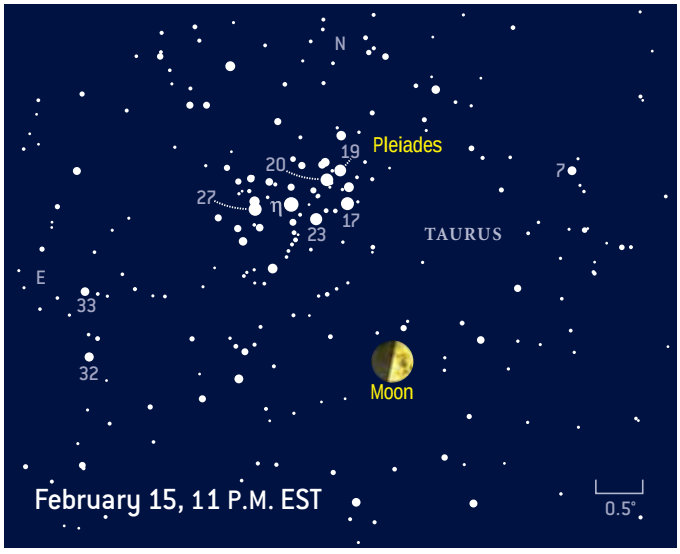
A Pleiades welcome

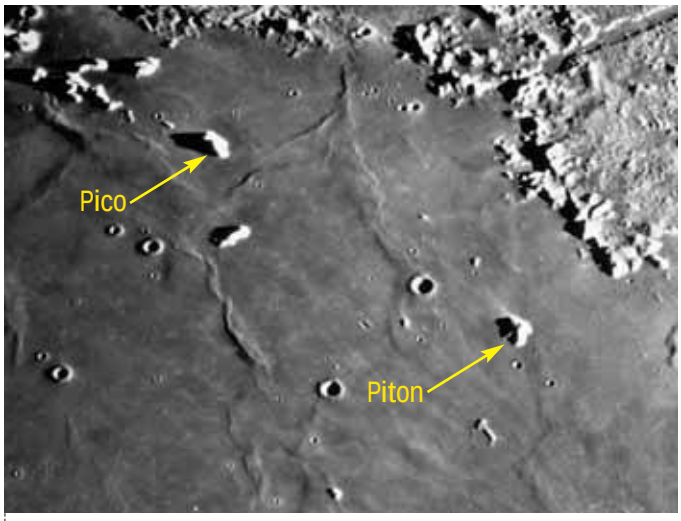
Few sights inspire backyard stargazers more than seeing the Moon pass near another prominent object. It happens most frequently with the bright planets and a handful of 1st-magnitude stars because the Moon returns to the vicinity of each once a lunar month. The best such events in February are gibbous Moon appearances near Jupiter (the 27th) and Saturn (the 19/20th) and a crescent Moon appearance near Antares (the 4th).

Much less often, the Moon makes a nice pass by a bright deep-sky object. These events are rare because only one deep-sky object — the Pleiades star cluster (M45) — combines the two essential ingredients: It shines bright enough to stand up to the Moon's brilliance, and it lies close enough to the Moon's path across the sky that our natural satellite occasionally comes near. Add in the fact that the cluster isn't so bright that it can rival a gibbous or Full Moon, and it's a wonder these close conjunctions aren't even more uncommon.

When the First Quarter Moon passes 1.2° south of the Pleiades the night of February 15/16, it marks the objects' first close encounter since the early 1990s. The long drought stems from the Pleiades' position relative to the lunar orbit. The cluster lies at a declination of 24°, on the northern part of the Moon's orbital path. For the past dozen years, the Moon has been well south of the Pleiades each time it made its monthly pass.

The good news: The Moon and Pleiades will be close each month for the next few years.





LUNAR MOUNTAINS PICO AND PITON rise out of the lava fields in northern Mare Imbrium, where they come into prominence around First Quarter phase. FROM *CONSOLIDATED LUNAR ATLAS* (LPL/UA)

The slow shift of the lunar orbit means once these events begin, they keep going for a good while. Later this year, the Moon actually starts to cross in front of the cluster. The two won't always appear real close, and at least half the time, the Moon's brightness will overwhelm M45. (The best views of a waxing crescent Moon near the cluster will come on spring evenings.) It's a series of events you won't want to miss.

Pico and Piton

Two huge mountain peaks lie south and southeast of Plato, a large, prominent crater in the northern part of the Moon's nearside. The two mountains join numerous others scattered across the flooded plain of Mare Imbrium. Mount Pico, closer to Plato, rises almost 8,000 feet from the lava plain. Slightly smaller Mount Piton pushes some 7,400 feet high.

Between the two peaks and nearer Piton, you can find a small crater called Piazzi Smyth. East of Piton lies the crater Cassini (see "Meteors and moons," November 2004).

The peaks of Pico and Piton catch the Sun's rays before the surrounding landscape and can, on occasion, appear as brilliant, star-like points beyond the advancing terminator. This occurs approximately 8 days after New Moon, or around First Quarter phase. Both mountains have complex peaks with ridges that dramatically alter their appearance as the Sun rises.

Prominent mountain ranges lie near both peaks. North of Mt. Piton lie the lunar Alps, named after the magnificent range in Europe. West of Mt. Pico are the Teneriffe Mountains, a cluster of peaks that dot the northern shore of the Imbrium basin.

COMETS AND ASTEROIDS

Times are good for comet enthusiasts in the Northern Hemisphere. From bright to faint objects and evening to morning sky, you have plenty to choose from.

Machholz shines on

Visible to the naked eye from dark sites, Comet C/2004 Q2 (Machholz) heads for the pole this month. Now that it is moving away from the brighter background sky of the Milky Way in Perseus and Cassiopeia, this round fuzzball should be easier to see, despite having faded slightly from its peak brightness in January. (The 5th-magnitude comet gave us a nice wide-field photo-op between January 28 and 31, when it crossed an area of glowing gas clouds.)

The first 10 days of February should be best because the Moon's light won't bathe the evening sky. Sweep with binoculars to the upper right of Cassiopeia's M outline. If you're having trouble seeing the comet, it may be that you're not waiting long enough to dark-adapt — it typically takes more than 20 minutes before your eyes fully adjust to the darkness.

There are no easy star patterns to latch onto in this rather sparse area of northern Cassiopeia and Camelopardalis unless you're a variable star observer. Comet Machholz should eclipse the well-known eclipsing binary RZ Cassiopeiae the evening of February 7. In an eclipsing binary system, the fainter star regularly moves in front of the brighter one, causing the pair to dim. In the case of RZ Cas, the pair fades from magnitude 6.2 to 7.7 in about 2.5 hours.

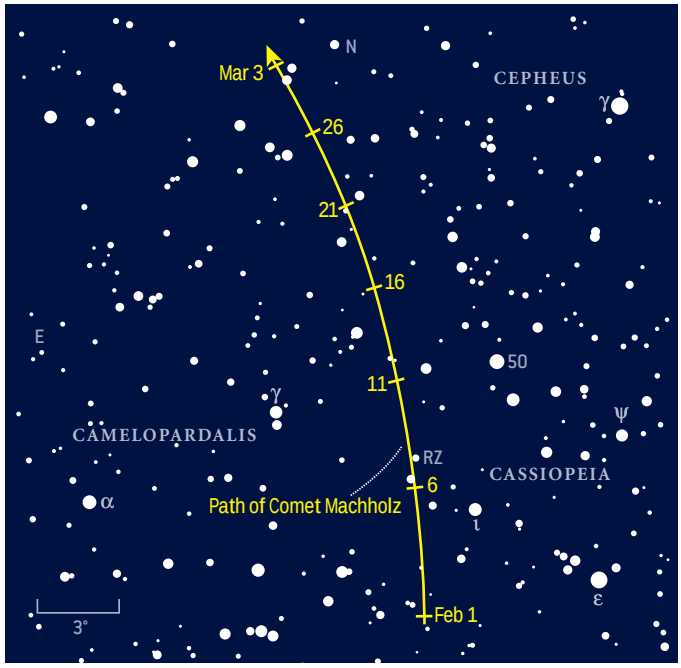
After a bright sojourn deep in the southern sky, Comet C/2003 K4 (LINEAR) returns to view for northerners. The comet appears low in the south during the evening hours, moving from Fornax into Eridanus. Aim your binoculars to the string of nine stars from Tau^1 (τ^1) to Tau^9 (τ^9) Eridani, then drop south a few degrees. The 8th-magnitude comet will be easy to see from the country, but you'll need a scope to view it from a city backyard.

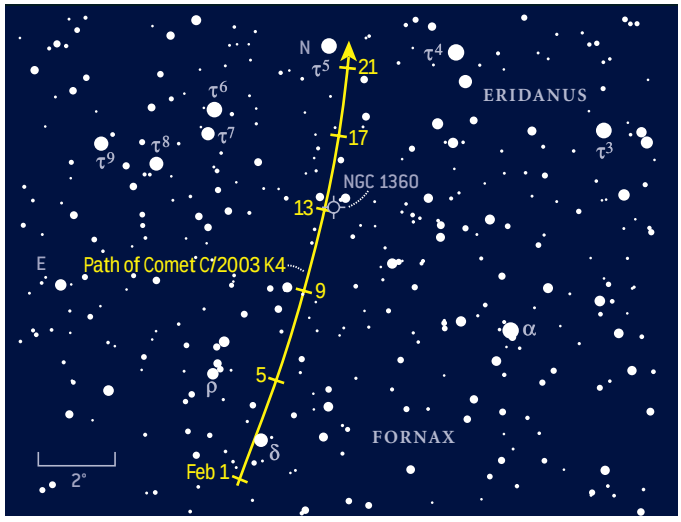
On the nights of February 13 and 14, C/2003 K4 lies less than an apparent Moon-width east of the large planetary nebula NGC 1360. Unfortunately, the nearby Moon will lighten the sky.

A third comet graces the predawn sky. Comet C/2003 T4 (LINEAR) should brighten to 8th magnitude or so this month, becoming a pleasant telescopic sight. In mid-February, it will be nicely framed by the Dumbbell Nebula (M27) in Vulpecula and M71, a loose globular star cluster in Sagitta.

High-numbered rock

Usually, brighter asteroids were discovered (and hence numbered) before fainter ones, so it's a rare treat to be able to track one with a high number. The one designated 532 Herculina has a modestly eccentric orbit, and this year, it lies near its perihelion, or closest point to the Sun, at the same time it reaches opposition. That's why it appears brighter than normal.





Spanning 129 miles, Herculina glows at magnitude 9.2 in early February. It floats in front of Gemini, quite close to the twin bright stars Castor and Pollux and slightly north of the even brighter Saturn. A second asteroid, 8 Flora, also lies nearby. It glows at 9th magnitude some 5° southwest of Herculina.

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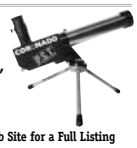

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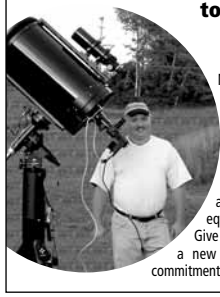

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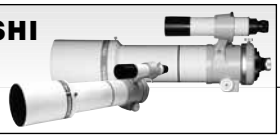

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The **Celestron 10 x 50mm LPR Optiview**, left, is a good conventional binocular that also has a secret weapon for astronomy. Built-in light pollution filters block the glare of city lights that can wash out faint deep space nebula detail.

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Simply move a cross-hair cursor over an object displayed on the 4096-color LCD star chart screen of the Sphinx Star Book hand control. Push a button and the Sphinx mount moves your scope to the object. Zoom buttons on the chart display also control the motor speed. Zoom in on an object on the screen and the motors slow for more accurate control. Zoom out and the motors speed up to cover large distances more quickly.

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NP-101 **$3595**

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All of the above refractors are optical tubes only, without mount, diagonal, eyepiece, or mounting ring, but all include a carrying case. These and many other complete optical tubes, with all the accessories mentioned, are also available from stock.

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Meade's brand-new Series 5000 eyepieces are available in 20 versions using three different advanced optical designs.

The seven new Plössls use five and six element optics and range from a high power 1.25" 5.5mm to a 2" 40mm. Each has a wide 60° field of view. Prices range from $89 to $199.

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Each has long eye relief, a twist-up rubber eyecup, and very good images.

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The C11S and C11S (XLT) have an adjustable height tripod with 2" steel legs, slow motion controls, setting circles, 40mm Plössl eyepiece, and 9 x 50mm finder. Starbright multicoatings are standard on the C11S. State-of-the-art XLT multicoatings on the C11S (XLT) give you 16% more light. An optional dual-axis drive is available for tracking with each scope.

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They are easy to transport and set up (the heaviest piece weighs only 29 lbs.) And, best of all, they are very affordable. A big scope no longer costs a fortune, thanks to Celestron.

11" Celestron C11S

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Celestron's NexImage captures the solar system for only $99.

There's a true CCD at the heart of the **Celestron NexImage Solar System Imager**. It's a Sony HAD full color 640 x 480 CCD with 5.4 micron pixels. It takes high power lunar/planetary images with any brand or size telescope and sends them to your computer to view live or print out later. At only $99, it makes serious solar system imaging affordable for everyone.

Some nifty accessories to make your observing easier.

Red night vision flashlights protect your dark-adapted vision while you're observing. **Celestron's** variable brightness flashlight (our part #VLED) is **$21.95**.

The **Rigel Systems** variable brightness light (#4591) shown is **$24.95**. Rigel's 2-color variable brightness light (#4592) – red for reading star charts, and blue-white for setting up and taking down your scope – is **$29.95**.

Put vibration suppression pads under the legs of your telescope or spotting scope tripod and you'll virtually end the tremors that blur your view for a few seconds each time a breeze comes up or you touch the scope to focus.

A set of three **Celestron** pads, part #VSP, costs **$49.50.** The **Meade** #895 pads to the right cost **$49.95.** Both sets dramatically improve your observing and are well worth their low cost.

Celestron Power Tank rechargeable 12-volt batteries have the power you need to run your telescope and accessories all night long. They can be recharged hundreds of times, saving you hundreds of dollars over the cost of constantly buying sets of flashlight batteries every few weeks. Each has *two* 12V DC cigarette lighter outputs; 3, 6, and 9V DC outputs for accessories; an emergency spotlight; built-in recharger; shoulder strap; carry handle; and more. The 7 amp hour Power Tank shown, our part #4512V, is only **$59.95**. The 17 amp hour Power Tank, our #4517V, is sale priced at only **$89.95**.

Take out the frills, like fancy boxes and and engraved barrels, but leave in the optical performance. What do you get? Wide angle eyepieces priced at only **$49** – far too low for the image quality you get. The **Burgess Optical** 1.25" wide fields are priced right for binoviewers. Available in 60° field 8mm or 12mm, a 65° field 17mm, and a 67° field 21mm.

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Cassini targets

The Cassini spacecraft opens a new chapter in the exploration of Titan, revealing Saturn's enigmatic moon to be diverse, complicated, and, possibly, geologically active. /// BY RICHARD TALCOTT

ON OCTOBER 26, THE CASSINI SPACECRAFT MADE ITS FIRST CLOSE PASS BY SATURN'S PLANET-SIZE MOON, TITAN. AFTER A 7-YEAR JOURNEY — THE LAST 4 MONTHS OF WHICH WERE SPENT IN ORBIT AROUND SATURN — CASSINI PLUNGED WITHIN 730 MILES (1,174 KILOMETERS) OF THE HAZE-SHROUDED WORLD'S SURFACE.

It snapped hundreds of photographs, made its first radar observations, and scooped up traces of the moon's outer atmosphere. Cassini even scouted the landing site for Huygens, an atmospheric and surface probe destined for Titan in January 2005.

"Unveiling Titan is like reading a mystery novel," says Charles Elachi, director of NASA's Jet Propulsion Laboratory (JPL). "Each time you flip the page, you learn something new, but you don't know the whole story until you've read the whole book."

Cassini's October flyby composed a tantalizing first chapter. It introduced a cast of characters that includes large regions of bright and dark terrain, wispy streaks on terra firma, and a nitrogen atmosphere eroding into space. Possible roles belong to carbon-rich rain or snow, and lakes of liquid hydrocarbons. Noticeably absent from the cast is any clear sign of impact craters, which suggests a geologically active surface.

SATURN: NASA/JPL/SSI; SPACECRAFT: NASA

TITAN

Although Titan has begun to yield its closely held secrets, planetary scientists have a long way to go before understanding the world. "We are still mystified," confesses Carolyn Porco of the Space Science Institute, leader of the imaging team. "We can't figure out what the features are, but they are intriguing. This is an environment we have never seen before."

Before the flyby, Titan boasted the largest unexplored surface in the solar system. When the twin Voyager spacecraft flew past the moon in the early 1980s, they were equipped with cameras that saw mainly visible-light wavelengths. Unfortunately, the haze that chokes Titan's atmosphere completely blocks visible light — the Voyagers left the saturnian system with no images of Titan's surface. In the intervening years, however, planetary scientists realized Titan's atmosphere was transparent in parts of the infrared spectrum. Cassini's cameras can "see" near-infrared as well as visible light, and the spacecraft's radar penetrates the atmosphere as if it weren't there.

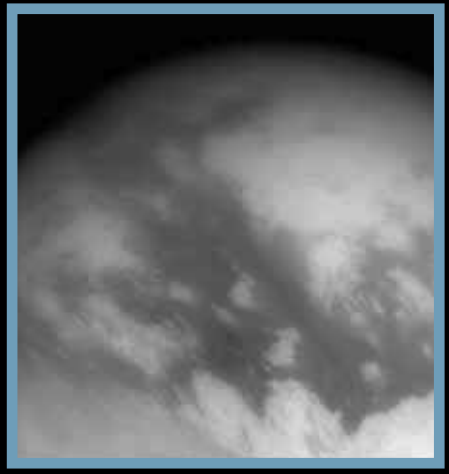
Cassini passed 210,000 miles (339,000 km) from the moon last July, just after the spacecraft entered orbit around Saturn, but the views from that distance lacked crisp detail and were more confusing than revealing. In October, Cassini came nearly 300 times closer. Details as small as several hundred feet (about 200 meters) across could be discerned, compared with tens of miles across in July. The viewing geometry for the close flyby was nearly ideal: The Sun shone from directly behind the spacecraft, increasing the imaging contrast by minimizing the haze's scattering effects.

Bright, dark, and streaky

The images reveal a high-contrast surface with a complex interplay between the bright and dark expanses. Although the bright areas appear cloud-like to the eye, that's only because we're conditioned to view white, diffuse features that way. Both the bright and dark areas are definitely surface features. The topography of the features, however, remains in doubt. Because the Sun lit the scene from directly behind the spacecraft, there are no shadows to help determine what's up and what's down.

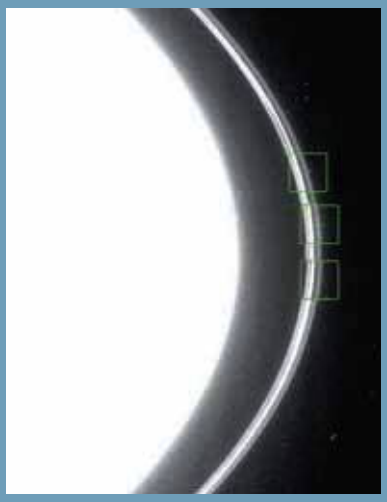
The surface also features a multitude of bright streaks. The streaks have planetary scientists seeing red — as in Red Planet. High-speed winds in Mars' atmosphere blow

A FALSE-COLOR TITAN comes from combining near-infrared observations (shown in red and green), which reveal the surface, with ultraviolet observations (in blue) that show the upper atmosphere. NASA/JPL/SSI



WIND MAY CAUSE the streaking seen across Titan's equatorial region. The streaks run east-west (upper left to lower right). NASA/JPL/SSI

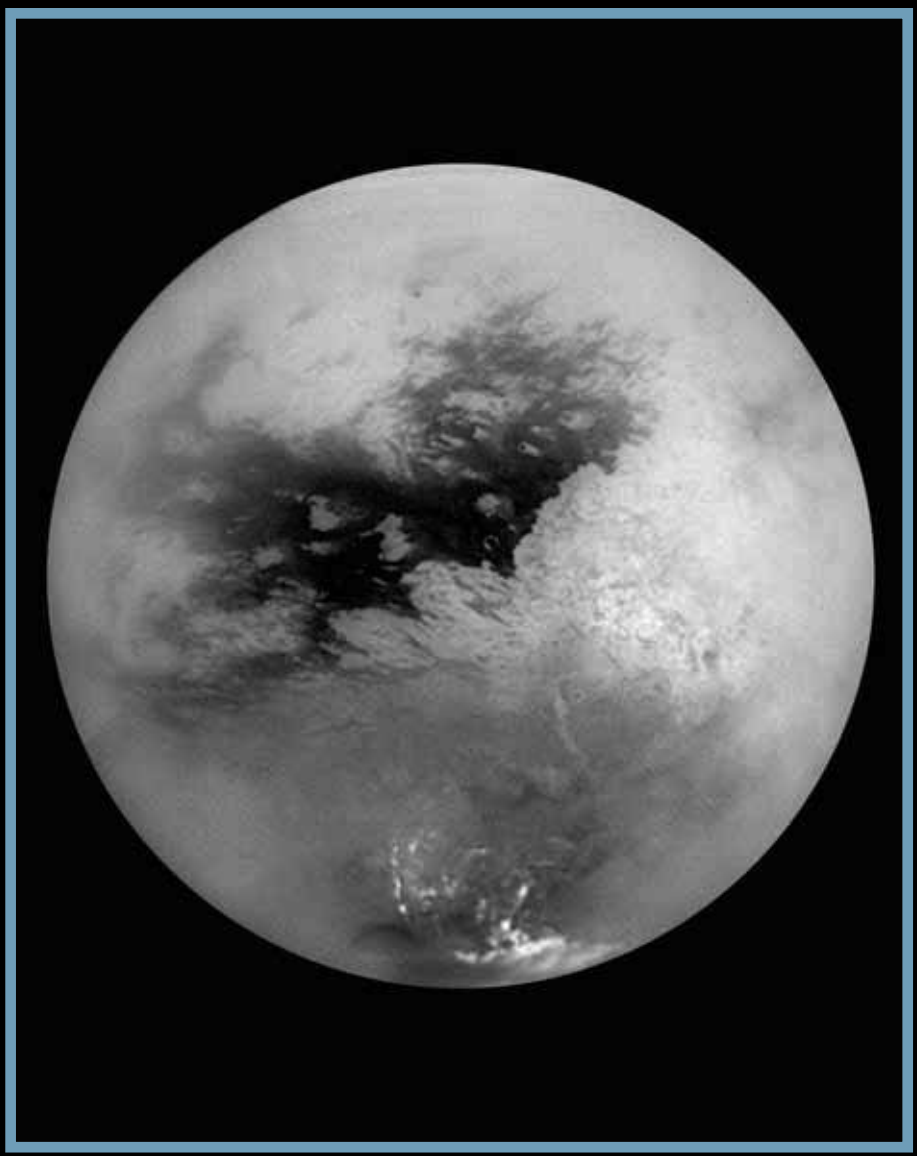
/// MOONS GALORE



A LIKELY NEW MOON orbits Saturn near the F Ring. Cassini imaged the object (inside the boxes) every 8 minutes. NASA/JPL/SSI

How many moons orbit Saturn? The count reached 37 in November, but you could safely bet that, as you're reading this, the number is higher. One of the tasks scientists set for Cassini was to search for undiscovered moons. On November 8, the imaging team announced two more moons, bringing Cassini's total to six.

All the moons appear to be small, probably a couple of miles across at most. At the scale of the discovery images, the moons take up just one pixel; the imaging team estimated the diameters based on brightness. All the new moons lie fairly close to Saturn. Two of them skirt the F Ring, two lie between the inner satellites Mimas and Enceladus, and the final two orbit in the vicinity of Tethys and Dione.



TITAN APPEARS IN ALL ITS GLORY in this nine-image mosaic, which was processed to sharpen surface features. Note the large cloud complex, which spans 600 miles, near the south pole; the bright area at right dubbed Xanadu; and the streaks running through the light and dark regions. NASA/JPL/SSI

that planet's ubiquitous dust, which collects in the lees of raised features to form conspicuous streaks.

The streaks on Titan appear similar, although that's no guarantee they are. For one thing, no topographic features have been seen yet on Titan's surface. For another, migrating ice sheets or flowing hydrocarbon liquids could cause such streaks. Still, imaging-team members suspect the moon's atmosphere plays the dominant role because most of the large streaks run parallel to Titan's equator, which coincides with the atmosphere's west-to-east circulation.

Cassini turned its radar instrument on Titan for the first time during the October flyby. The radar beam captured a swath of the surface measuring about 1,250 miles (2,000 km) long and 75 miles (120 km) wide — approximately 1 percent of Titan's surface area. Details as small as 1,000 feet (300 meters) across can be seen. However, the region studied with radar does not coincide with the region imaged by the cameras.

Like the camera observations, the radar shows bright and dark areas, although not for the same reason. With radar, bright areas typically correspond to rougher terrain, and darker regions to smoother terrain.

Elachi, who also heads the radar team, thinks some of the dark areas could be lakes of liquid hydrocarbons. Planetary scientists suspect such lakes might exist on Titan's surface. The atmosphere contains organic compounds, like methane and ethane, that could rain out and exist as a liquid at Titan's frigid surface temperature of –290° Fahrenheit (–180° Celsius).

Still, neither the radar experiment nor imaging cameras detected any specular reflections, or bright glints, coming off a liquid surface. "We see no evidence of specular reflection on Titan," says Porco, "and we should have seen it if it were there." Radar observations from Earth have shown such reflections, however, so Cassini scientists will keep a lookout during future flybys.

Lots of linear features also appear in the radar images. "They are likely ridges, and they remind me of the ridges we saw in radar images of Venus," says Elachi. Cassini's radar experiment also includes an altimeter to

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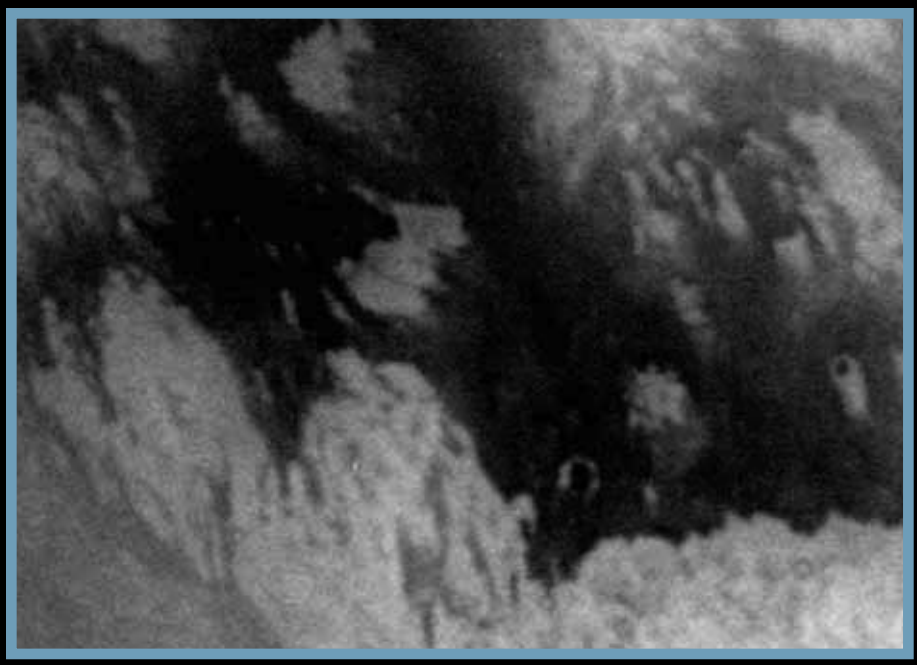
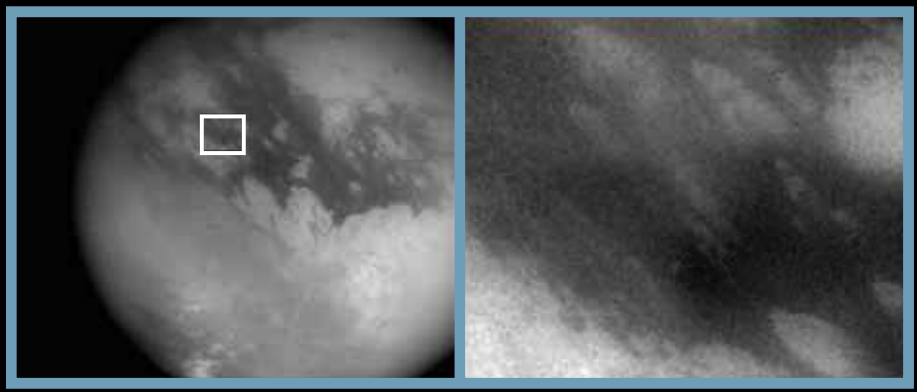
Richard Talcott *is a senior editor of* Astronomy.



THE COMPLEX INTERPLAY between light and dark areas shows up vividly in this image, which spans 1,200 miles. Scientists have started calling the light area near center "Great Britain." NASA/JPL/SSI



THE HUYGENS LANDING SITE has scientists excited, especially after they saw the first close-up Cassini images showing bright and dark streaks there. A wide-angle image (left) shows features as small as 6 miles across, while a close-up view (right) has details down to 0.5 mile. NASA/JPL/SSI

measure the height of surface features. The region it covered appeared remarkably flat, with variations in height of only about 500 feet (150 meters), roughly the same amount of relief seen in the state of Delaware. The altimeter measured a track 250 miles (400 km) long, but, because of the instrument's design, in a different region of Titan than the radar measurements.

The radar experiment also can operate in a third mode. As team member Ralph Lorenz of the University of Arizona explains: "With the radar in its active mode, it is like shouting at Titan and listening for the echoes. But we can also just listen to Titan with the sensitive radar receiver; this is the radiometry."

The radiometry confirmed observations made with the Visual and Infrared Mapping Spectrometer (VIMS) that showed a surprisingly uniform surface of carbon-containing compounds, with little difference in composition between the light and dark areas. "Titan is not an iceball," says Lorenz. "It must be covered with organic material of some kind, just covered with the stuff."

Making an impact

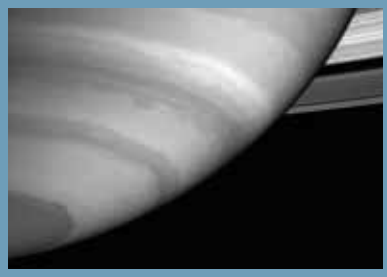
One type of surface feature proved conspicuous by its absence. Neither the imaging cameras nor the radar experiment saw any clear-cut evidence of impact craters, and only hints of a few possibly buried craters.

Planetary scientists count impact craters to deduce the age of an object's surface — the more craters, the older it is. On Earth's Moon, for example, the lightly cratered maria are several hundred million years younger than the heavily cratered highlands.

"The fact that we have seen few craters tells us that Titan's surface is young," says Jonathan Lunine of the University of Arizona, an interdisciplinary scientist on the Cassini mission. Saturn's other moons bear innumerable impact scars, so their absence on Titan implies something has removed them. "Titan is a dynamic place, with complex geological processes that appear to be shaping its surface," adds Lunine.

What those processes might be, however, remains a mystery. Lunine suggests it could be some form of icy volcanism. At a temperature of –290° F, ice at Titan's surface has properties more akin to bedrock than to the ice we're familiar with on Earth. Nevertheless,

/// BACK AT THE PLANET



SWIRLS AND BANDS dominate Saturn's southern hemisphere. NASA/JPL/SSI

With all the hoopla about the first Titan flyby and the impending Huygens landing, it might be tempting to think that Cassini erupts into a flurry of activity only when it nears a close encounter with this fascinating moon. Not true — Cassini constantly observes Saturn, the rings, and the other moons as it continues orbiting the planet. The spacecraft has monitored several massive storms in the planet's atmosphere, searched for (but has yet to find) the ring spokes seen originally by Voyager, and taken distant shots of the other large moons in preparation for close flybys in 2005. (See "What's ahead for Cassini?" on page 77.)

DENSITY WAVES show up in Saturn's A Ring. NASA/JPL/UNIVERSITY OF COLORADO AT BOULDER

/// COUNTDOWN TO LANDING

HUYGENS WILL PARACHUTE to a landing on Titan January 14. Whether it will land in a liquid lake, on solid, rock-hard ice, or in a mushy hydrocarbon ooze, remains totally up in the air. NASA/ESA

If all goes according to plan, the Huygens probe will parachute through Titan's atmosphere and land on the surface January 14. The odds of success got a big boost from Cassini's October flyby.

Planetary scientists wanted to test their models of Titan's atmosphere — which were used to plan the probe's entry and descent — to see how closely they matched reality. The models came through with flying colors. The flyby also confirmed that Cassini can get even closer to Titan on future flybys, some of which could dip to within 590 miles (1,200 km) of the moon's surface.

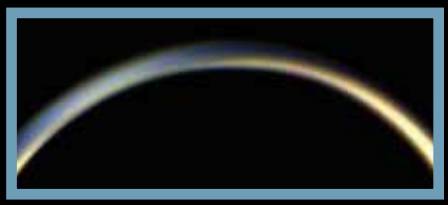
But Cassini images of Huygens' landing site excited scientists even further. The site lies in a diverse area of bright and dark terrain that includes some streaks. "I don't think we could have picked a better landing site if we had tried," says Jean-Pierre Lebreton of the European Space Agency, project scientist for Huygens. The site was chosen based on spacecraft requirements and not on scientific interest, so the Huygens team feels lucky.

No one knows what Huygens will find as it descends to the surface. Mark Leese of the United Kingdom's Open University, program manager for the probe's surface instruments, says: "It's interesting that all of the possible landing scenarios we envisaged — a hard crunch onto ice, a softer squelch into solid organics, or a splashdown on a liquid hydrocarbon lake — still seem to exist on Titan."

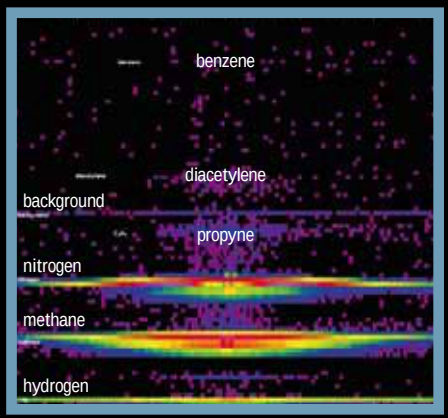
Huygens carries six instruments. Four of the instruments will study Titan's atmosphere as the probe makes its 3-hour descent, measuring the atmosphere's temperature, density, pressure, wind speed, and composition.

A descent imager will photograph the moon's surface around the landing site. (A lamp will switch on just before landing to augment the weak sunlight.) And finally, the Surface Science Package will determine the physical properties of the surface, regardless of whether the probe lands on solid ground or in a lake. All the information will be sent on to the Cassini orbiter, which will relay the precious data back to eager scientists on Earth.

A DETACHED HAZE LAYER and several discrete, cloud-like features appear above Titan's north pole. Although the surface is in darkness, the clouds are high enough to be sunlit. NASA/JPL/SSI



LOOKING BACK after closest approach, Cassini captured Titan's atmosphere from the night side, as small haze particles scatter sunlight toward the camera. NASA/JPL/SSI



THE OUTER ATMOSPHERE of Titan bubbles with nitrogen, hydrogen, and a hydrocarbon stew. Cassini's INMS sampled the air to within 730 miles of the surface. NASA/JPL/UNIVERSITY OF MICHIGAN

some sort of chemical "antifreeze" could turn the ice to slush and help drive the activity. Keep in mind that Neptune's largest moon, Triton, is much colder than Titan and still has ice volcanoes.

Assuming liquids are, or at least were, common on Titan's surface, waves might have eroded the craters. The organic material that seems to coat the surface raises a third possibility: The craters simply could be hidden from view. Organic compounds raining — or snowing — out of the atmosphere over the eons could have buried any impact craters under a thick sludge.

Another Cassini instrument, the magnetometer, attempted to probe beneath Titan's surface. The magnetometer studied how Titan's atmosphere and ionosphere interact with charged particles in Saturn's powerful magnetic field. It was looking for signs that Titan has an internal magnetic field.

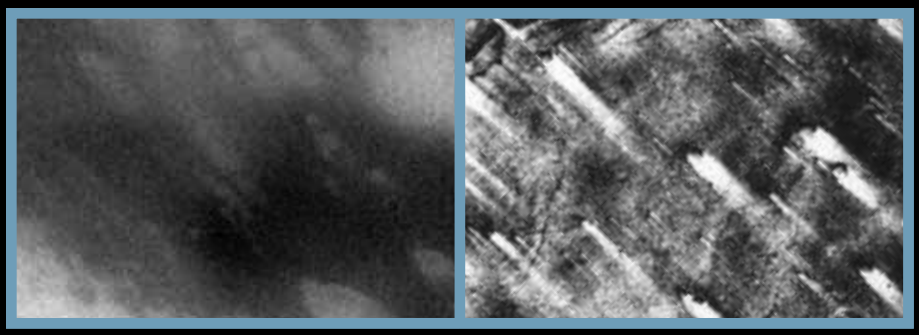
The experiment didn't detect one, at least during this flyby, although observations planned for the close pass in December should give a better idea. "All we can say at this point is that if there is a magnetic field generated in the interior of Titan, it is very small," declares team leader Michele Dougherty of Imperial College in London.

A breath of air

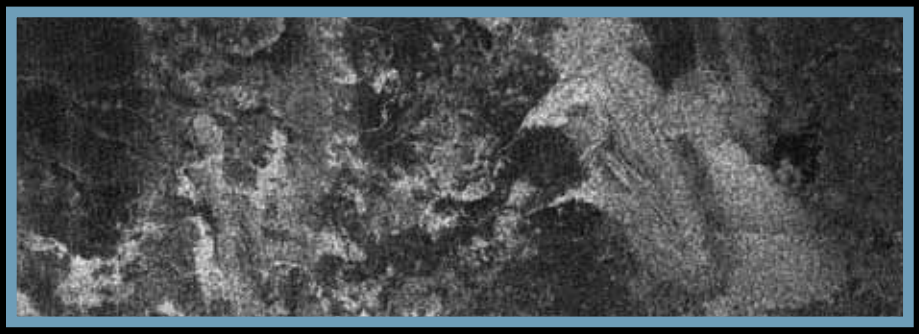
The most intriguing characteristic of Titan has to be its dense atmosphere. It is the only moon in the solar system with more than a trace of air surrounding it, and the atmosphere's pressure and density exceed those of Earth's. And just like on Earth, nitrogen makes up the bulk of the atmosphere. Many planetary scientists think Titan preserves in a deep freeze a similar environment to that of the early Earth, when life gained a foothold.

As Cassini flew past Titan, the spacecraft's Ion and Neutral Mass Spectrometer (INMS) scooped up molecules lurking at the outer edge of the moon's atmosphere. It found a rich mix of organic molecules, including methane, benzene, and diacetylene, along with the ever-present nitrogen.

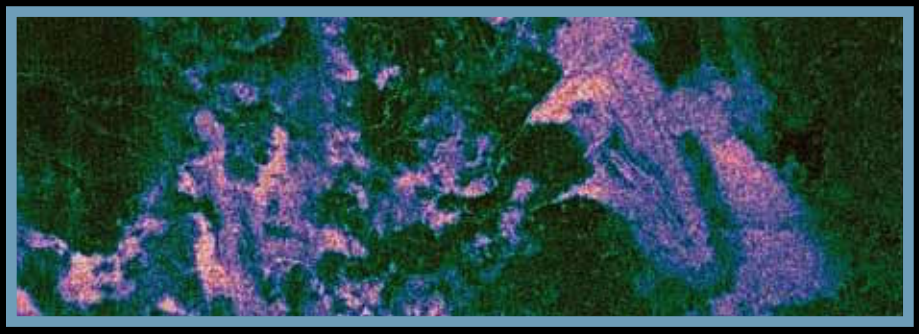
But the most significant discovery made by the INMS is that Titan may have lost three-quarters of its atmosphere over the age of the solar system. The team measured the ratio of nitrogen-15 to nitrogen-14 in the upper atmosphere. Normally, nitrogen contains



STREAKS APPEAR COMMON on both Titan (left) and Mars (right). Planetary scientists know the martian streaks are created by the wind, and they suspect the same may be true on Titan. NASA/JPL/SSI



CASSINI'S FIRST RADAR OBSERVATIONS of Titan reveal a variety of geologic terrain, with bright areas representing rougher surfaces and dark areas smoother terrain — and perhaps liquid. NASA/JPL



FINER DETAILS POP OUT from Titan's surface in this false-color radar image. The winding, linear features that show up well appear to be ridges, perhaps similar to those seen on Venus. NASA/JPL

/// WHAT'S AHEAD FOR CASSINI?

Cassini has a busy agenda for 2005. The October 26, 2004, flyby of Titan not only resulted in outstanding science, but it also modified the spacecraft's orbit. Prior to the encounter, Cassini took 4 months to orbit Saturn; after, its orbital period shrunk to 48 days. The tighter orbit means more flybys of saturnian moons. The spacecraft was scheduled to swoop past Titan again December 13 and make a distant pass of Iapetus New Year's Eve.

The table lists all 16 flybys scheduled for 2005, which include close passes by seven of the eight major moons (all except Iapetus). The distant Titan flyby January 14 coincides with the arrival of the Huygens probe. Cassini will relay that data to Earth. Keep up-to-date on all Cassini and Huygens results in the pages of *Astronomy* and on-line at Astronomy.com.

Moon	Date	Closest approach
Titan	Jan 14	37,290 miles
Titan	Feb 15	590 miles
Enceladus	Feb 16	733 miles
Enceladus	March 9	311 miles
Titan	March 31	1,568 miles
Titan	April 16	590 miles
Enceladus	July 14	622 miles
Mimas	Aug 1	28,030 miles
Titan	Aug 22	2,495 miles
Titan	Sept 7	590 miles
Tethys	Sept 23	20,510 miles
Hyperion	Sept 25	615 miles
Dione	Oct 11	311 miles
Titan	Oct 27	899 miles
Rhea	Nov 26	311 miles
Titan	Dec 26	6,482 miles

seven protons and seven neutrons in its nucleus. In less than 1 percent of atoms, however, a nitrogen nucleus contains seven protons and eight neutrons. Molecules made with the heavier isotope are less likely to escape an atmosphere.

INMS team leader Hunter Waite of the University of Michigan says the nitrogen-15 to nitrogen-14 ratio is "off the scale" — far higher than the ratios seen on Earth, Venus, Mars, and Jupiter. "This is a strong indication that Titan has lost as much as three-fourths of its atmosphere over geologic time," says Waite. That makes the source of Titan's still-massive atmosphere even more mysterious.

One thing the atmosphere seems to lack, at least in large number, is clouds. Beyond the large complex first seen near Titan's south pole in July, clouds appear sparingly. Surprisingly, that cloud complex had roughly doubled in size by October, measuring some 600 miles (1,000 km) across. Even more remarkable, the clouds may not be made of methane, as virtually everyone had assumed.

Robert Brown of the University of Arizona, team leader for VIMS, says the clouds appear brighter when viewed at longer wavelengths. That indicates the particles making up the clouds are bigger than 5 micrometers in diameter, much larger than methane would be. Some other hydrocarbon could be the culprit, or, perhaps, the clouds really are made of methane and some unusual process masks its signature.

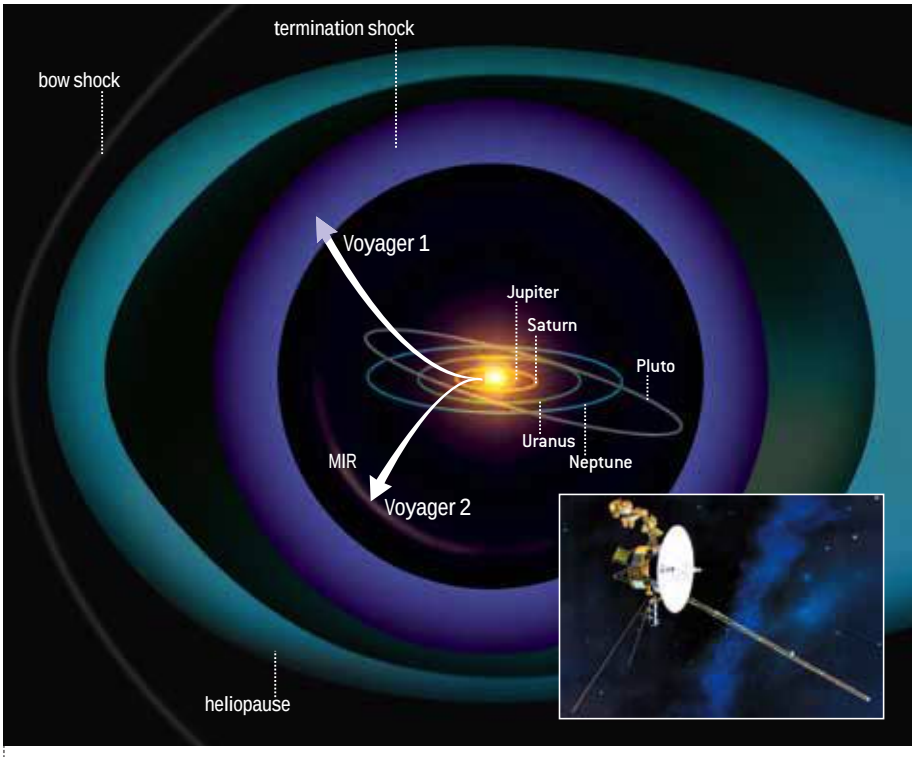
Cassini's October flyby has left Titan only slightly less mysterious than before. Because most of the instruments can cover only a limited area during each flyby — and typically not the same area as each other — it may take a high percentage of the 44 flybys planned during the next 4 years to solve the moon's mysteries.

"It's as if we're building a jigsaw puzzle without the top of the box," says Lunine. "It will be necessary to piece together the clues provided by Cassini and Huygens over the next few years. Sometimes, we'll be wrong, and we'll need to take the pieces apart and reassemble them again until, finally, a complete picture of the nature and evolution of Titan pops into view." A

To see a photo gallery of the latest Cassini images, visit www.astronomy.com/toc

ASK ASTRO

Seeking Voyager, quality optics, Planet X



LAUNCHED IN 1977, both Voyagers flew past Jupiter and Saturn, and Voyager 2 remains the only probe to have viewed Uranus and Neptune up close. A Merged Interaction Region (MIR), a remnant of 2003's solar storms, swept past Voyager 2 (inset) last year. Engineers expect both craft will return data beyond 2020. *ASTRONOMY:* ROEN KELLY; INSET: NASA/JPL

SEEKING VOYAGER

Whatever happened to the Voyager spacecraft?

— EARL CAMPBELL, NEWPORT, TENNESSEE

Both spacecraft are alive and well, returning science data each day. After traveling through space for more than 27 years, Voyager 1 is now nearly 8.8 billion miles (14.2 billion kilometers, or 94.6 AU) from the Sun, heading in a northerly direction toward interstellar space. On February 17, 1998, Voyager 1 exceeded Pioneer 10's distance from the Sun and became the most distant human-made object. Voyager 2 is now about 7 billion miles (11.3 billion km, or 75.7 AU) away, and is headed on a southerly course toward interstellar space.

As the two Voyagers near the edge of the heliosphere, the area dominated by the Sun's influence, they are returning valuable information on the composition and dynamics of the far solar wind and on solar outbursts billowing away from the Sun. Last year, the Voyagers participated in tracking remnants of the massive gas clouds that erupted from the Sun during the Halloween Storms of October and November 2003. Some of the most powerful flares ever recorded hurled billion-ton clouds of ionized gas — called coronal mass ejections (CMEs) — through the solar system. Faster CMEs combined with slower ones to form what scientists call a Merged Interaction Region (MIR). By the time the resulting shock reached Voyager 2 April 28, 2004, it had slowed to about one-third of its original speed, passing the spacecraft at 1.5 million miles per hour (2.4 million km/h). Predictions called for the cloud to pass Voyager 1 by the end of June, but the spacecraft did not detect it.

As the MIR moves outward from the Sun, it eventually will cross the termination shock, where the solar wind collides with the interstellar wind and slows. From there, the gas will continue until it reaches the heliopause, the edge of the heliosphere. There, it will mix with cooler gas in the interstellar medium.

If the MIR has retained sufficient energy, this event will create low-frequency radio waves that both Voyagers can detect. Scientists can calculate the distance to the heliopause — and, by inference, the termination shock — by comparing the arrival time of the MIR's radio signal with the time the shock passed the spacecraft. One of the science goals of what we now call the Voyager Interstellar Mission is to encounter the termination shock so we can observe interactions between the solar wind and its interstellar counterpart.

In fact, Voyager 1 may be close already. Recent observations indicate Voyager 1 is in a region unlike any it has encountered in all its years of exploration. Some scientists believe Voyager 1 has begun its passage through the termination shock, but the phenomena we observe are somewhat different than what was expected. So the debate continues while scientists try to understand what the spacecraft's instruments are telling us. If Voyager 1 has encountered the termination shock, it would be the first spacecraft to have entered the solar system's final frontier, a

vast expanse where wind from the Sun blows hot against the thin, cold gas between the stars. — ED B. MASSEY, JET PROPULSION LABORATORY, PASADENA, CALIFORNIA

QUALITY OPTICS

How do I tell if a telescope I'm interested in buying has high-quality optics? — JACOB COLBORN, CALABASH, NORTH CAROLINA

This is the first question any prospective telescope buyer should ask. Here are four key points to help you evaluate a telescope's optics.

First, get to know the marketplace, and select a scope from a well-known manufacturer. Become familiar with manufacturers and their wares by, for example, browsing ads in the pages of *Astronomy*. Aside from getting the best quality scope for your money, purchasing from an established company assures you of good return and repair policies. Once you've found something you like, visit the manufacturer's web site. This is where you'll find the most up-to-date information on specific scope models.

Second, price is a factor. Even small refractors with multi-element lenses will take a big bite out of your budget.

Third, try to observe with the telescope you've selected before you buy. If you live in a large city, there's probably an astronomy club nearby. Some of its members likely own the same scope, mount, and accessories that interest you.

Finally, listen to what other amateur astronomers have to say. Amateurs have a huge amount of experience. Many are members of astronomy clubs, and they love to share views through their scopes and chat about equipment. A good place to start is the Equipment section of *Astronomy*'s own on-line forum. See the box below for the address, or look under the Resources section at Astronomy.com. — MICHAEL E. BAKICH, ASSOCIATE EDITOR

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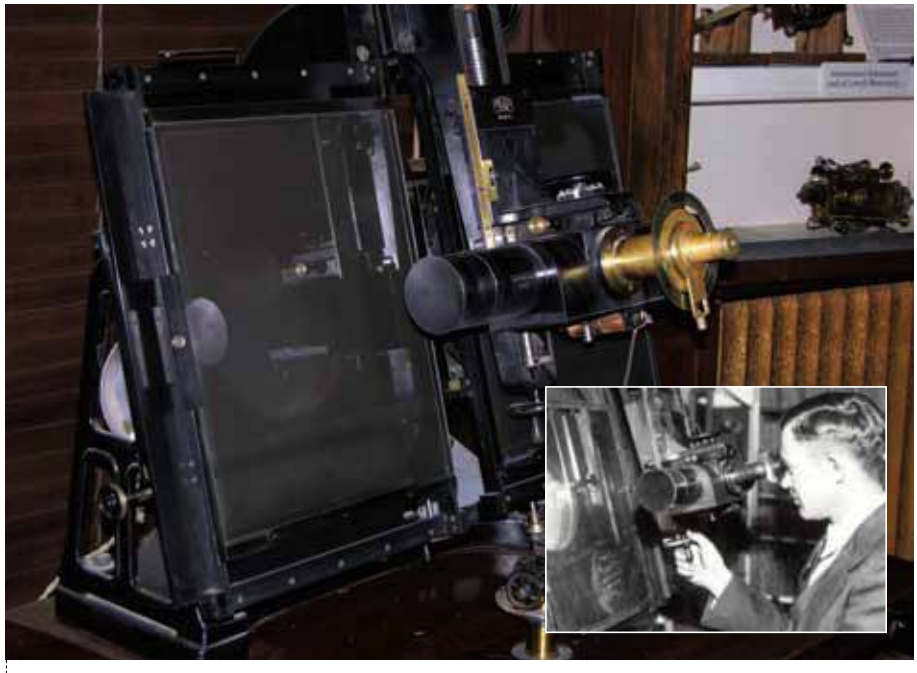


TO FIND BODIES BEYOND THE KUIPER BELT, astronomers survey the entire sky and look for slow-moving objects. Clyde Tombaugh found Pluto 75 years ago this month in a similar survey at Lowell Observatory in Flagstaff, Arizona. He used a blink comparator (above) to study two photographs of the same field taken at different times. *Inset:* Tombaugh demonstrates the device. LOWELL OBSERVATORY

PLANET X

Are astronomers still looking for "Planet X," a 10th planet in our solar system? — SARAH DRUMMOND, NELSONIA, VIRGINIA

For most of the 20th century, some astronomers were convinced that a 10th planet — Planet X — lay somewhere beyond Neptune. They inferred the existence of such a planet by its apparent effects on the positions of Uranus and Neptune. Both planets seemed to be tugged along slightly faster than expected, as if in response to the gravitational pull of another body. In 1993, astronomer Myles Standish of the Jet Propulsion Laboratory in Pasadena, California, performed a thorough reanalysis of all the old positional data. He concluded that Uranus and Neptune are exactly where we expect them to be and that no evidence for Planet X exists.

But that doesn't mean the hunt for Planet X has been called off. The past decade has seen the discovery of almost 1,000 icy bodies in the region beyond Neptune known as the Kuiper Belt. But the Kuiper Belt appears to have a sharp outer edge at about 50 AU, and what lies beyond is still almost completely unknown. My colleagues and I found the distant, almost-planetary-size body Sedna last year. Lying well beyond the Kuiper Belt, Sedna may be an indicator that it is only a matter of time before we find more and larger objects at the solar system's outskirts.

Such extremely distant planets would be too far away to affect the known planets' orbits measurably. The only way to find them is to use the technique employed by Clyde Tombaugh to find Pluto: Search the sky for slow-moving objects. The survey I am running at Palomar Observatory has been operating for 2½ years and will need another 2½ years before it has covered most of the sky. By then, we should know for sure if Planet X is out there, within reach of our current technology. — MIKE BROWN, CALIFORNIA INSTITUTE OF TECHNOLOGY

The deaths of stars in our part of the galaxy have produced a slew of beautiful targets for amateur astronomers. /// BY DOUG SNYDER

See a star die

THE RING NEBULA (M57) in Lyra is probably the best known of all planetary nebulae. MARK HANSON

It's the darkest, clearest night you've seen since you moved to the countryside, away from city lights. You gaze at a sky of beckoning stars, galaxies, and loosely defined regions of nebulosity, some of which are visible to the naked eye. But beyond your vision, wonders exist that no human eye beheld until just 240 years ago.

These wonders are planetary nebulae — stars passing through the celestial gate of life but that still propagate their stellar weave back into the fabric of the universe.

Cream of the crop

Planetary nebulae come in a variety of sizes, shapes, orientations, and ages. None was discovered until 1764 — 155 years after the invention of the telescope.

French comet hunter Charles Messier first observed the **Dumbbell Nebula** (M27) that year and placed the object in his now-famous catalog. Messier's entry for this new class of objects was the first ever recorded, although it was William Herschel in 1785 who coined the term *planetary nebula*.

To this day, the Dumbbell Nebula remains one of the most spectacular and popular planetaries among observers. Of the four planetaries found in Messier's catalog, M27 is the largest and brightest.

In addition to the Dumbbell Nebula, which lies in the northern constellation Vulpecula, Messier included three additional planetaries in his catalog. The **Ring Nebula** (M57) is located in the constellation Lyra and, like M27, is a summer object. With its smoky halo, a not-quite-transparent center, and challenging 15th-magnitude central star, the Ring Nebula is, without doubt, the most widely observed planetary.

In autumn, we find another "dumbbell" in the constellation Perseus. The **Little Dumbbell Nebula** (M76) is a great object to observe through telescopes of all sizes. In a small scope, M76 displays a boxy, irregular shape with shades of gray. A closer examination with higher power will enhance the twin lobes of this bipolar planetary nebula.

Moving into the spring sky, we come across the final Messier planetary — the **Owl Nebula** (M97). Located in Ursa Major less than 1° southeast of the galaxy M108, this round planetary was named by Lord Rosse in 1850. Rosse noticed two low-contrast, dark patches placed symmetrically near the object's center, which give it the appearance of an owl's face. Each of these Messier planetary nebulae is a visual delight, worthy of repeated observations.

An example of a winter planetary is the **Eskimo Nebula** (NGC 2392). It's located in Gemini the Twins, and while not large, it exhibits a pleasing bluish hue. Viewing NGC 2392 with larger apertures and at high magnification reveals its double shell. The Eskimo's easily observed magnitude 10 central star enhances the illusion of a face.

THE DUMBBELL NEBULA (M27) in Vulpecula was the first planetary nebula discovered, in 1764. MARK HANSON

THE OWL NEBULA (M97) in Ursa Major resembles a ghostly owl in a dark sky even through small telescopes. ADAM BLOCK

NGC 2438 in Puppis is fun to find and provides an interesting contrast to its surroundings comprising the rich open star cluster M46. ADAM BLOCK

THE ESKIMO NEBULA (NGC 2392) in Gemini reveals a subtle bluish color in small telescopes and good detail in large scopes. ADAM BLOCK

THE GHOST OF JUPITER (NGC 3242) in Hydra resembles its planetary namesake when viewed through a small telescope. ADAM BLOCK

THE LITTLE DUMBBELL (M76) in Perseus is a planetary nebula whose brightest area is rectangular in shape. ADAM BLOCK

Becoming a planetary nebula

"Planetary nebula" is the term for a dying Sun-like star that will evolve into a white dwarf. Stars with masses from 1 to about 8 suns form planetary nebulae. About 95 percent of stars will evolve into white dwarfs.

The evolution of a star into a planetary nebula can be summarized in six phases: (1) A Sun-like star forms. (2) After billions of years, the star enters its red-giant phase. (3) For a few million years, the star expands, and its outer layers cool. (4) A protoplanetary nebula, the precursor to a planetary nebula, forms. (5) The star expels its outer layers and enters the brief planetary-nebula phase. The estimated life span for planetary nebulae varies from 10,000 to 30,000 years — a snap of the fingers, astronomically speaking. (6) The central part of the star becomes a white dwarf. Radiation from this stellar corpse illuminates the planetary nebula until its distance from the star becomes so great that it stops glowing.

/// 20 GREAT PLANETARY NEBULAE

Designation	Common name	Constellation	Season	Right ascension	Declination	Size (")	Mag.	C. Star mag.
NGC 246		Cetus	Autumn	0h47m	–11°52'	240 x 210	10.5	13.4
NGC 650/651 (M76)	Little Dumbbell	Perseus	Autumn	1h42m	51°34'	90 x 45	10.5	16.3
NGC 1514		Taurus	Winter	4h09m	30°46'	120 x 90	10	9.4
IC 418		Lepus	Winter	5h27m	–12°42'	14 x 11	10.7	10.1
NGC 2371/2372		Gemini	Winter	7h26m	29°29'	54 x 35	13	14.8
NGC 2392	Eskimo Nebula	Gemini	Winter	7h29m	20°55'	47 x 43	9.9	10.4
NGC 2438		Puppis	Winter	7h42m	–14°44'	68 x 68	10.1	17.7
NGC 3132	Eight Burst Nebula	Vela	Spring	10h07m	–40°26'	30 x 30	8.2	10
NGC 3242	Ghost of Jupiter	Hydra	Spring	10h25m	–18°38'	35 x 35	8.6	13.3
NGC 3587(M97)	Owl Nebula	Ursa Major	Spring	11h15m	55°01'	180 x 180	12	16
NGC 6543	Cat's Eye Nebula	Draco	Summer	17h59m	66°38'	23 x 18	8.8	10.9
NGC 6572		Ophiuchus	Summer	18h12m	6°13'	15 x 15	9	13.6
NGC 6720 (M57)	Ring Nebula	Lyra	Summer	18h54m	33°44'	85 x 62	9.7	15
NGC 6818	Little Gem	Sagittarius	Summer	19h44m	–14°09'	22 x 15	10	16.9
NGC 6826	Blinking Planetary	Cygnus	Summer	19h45m	50°31'	27 x 24	9.8	10.6
NGC 6853(M27)	Dumbbell Nebula	Vulpecula	Summer	19h59m	22°43'	480 x 340	7.6	12
NGC 6905	Blue Flash Nebula	Delphinus	Summer	20h22m	20°06'	44 x 37	11.9	14.2
NGC 7009	Saturn Nebula	Aquarius	Autumn	21h04m	–11°22'	39 x 30	8.3	11.9
NGC 7293	Helix Nebula	Aquarius	Autumn	22h30m	–20°50'	900 x 720	7.5	13.4
NGC 7662	Blue Snowball	Andromeda	Autumn	23h26m	42°32'	17 x 14	8.6	12.7

To locate these planetary nebulae, log in to Astronomy's "Star Dome" at www.astronomy.com/toc

The physics of observing planetaries

Two key factors make planetary nebulae observable: ultraviolet (UV) radiation and ionization. UV radiation from the white dwarf star is the energy source. The combination of a hot central star, low-density gas, and UV radiation gives telescopic observers a fair number of planetary nebulae to view with colors ranging from blue to green.

Ionization is the process of stripping electrons from an atom. In planetary nebulae, this occurs when electrons absorb UV radiation. Loose electrons eventually recombine with atoms that have lost electrons, however. At this point, visible light (emission radiation) is emitted in distinct colors.

In planetary nebulae, the most prominent radiation results from the double ionization of oxygen atoms, which is designated OIII. The wavelengths of this particular process are 495.9 and 500.7 nanometers in the greenish-blue area of the visible spectrum. More planetaries exhibit color through the eyepiece than any other type of extended celestial object.

Pass a filter, please

Although colors can be seen in several planetary nebulae without using a filter, most of these objects are enhanced visually by a narrowband wavelength filter. These filters are known by the names Oxygen III (OIII) and Ultra High Contrast (UHC). A typical UHC filter passes a wider span of wavelengths than an OIII filter and, therefore, is usually the second choice among observers for viewing these objects.

Another benefit from using one of these filters, especially an OIII, is that planetaries that look like stars and those located within crowded star fields stand out more. Because normal stars do not emit strongly in the part of the spectrum where the OIII line is located, the filter blocks most starlight. Starlike planetary nebulae, on the other hand, will be visible through the filter.

Tips for observing planetaries

Dark adaption is the paramount factor in visually observing planetary nebulae. Using a red-filtered or red LED light (preferably one that can be dimmed) to view charts will help maintain your night vision.

"Blinking" is a technique used by observers to enhance viewing of an object intermittently. Two common variations of this technique are used for observing these nebulae. The first involves a narrowband filter moved repeatedly between your eye and the eyepiece. Repeat this step as necessary to determine any changes in the object. Stray

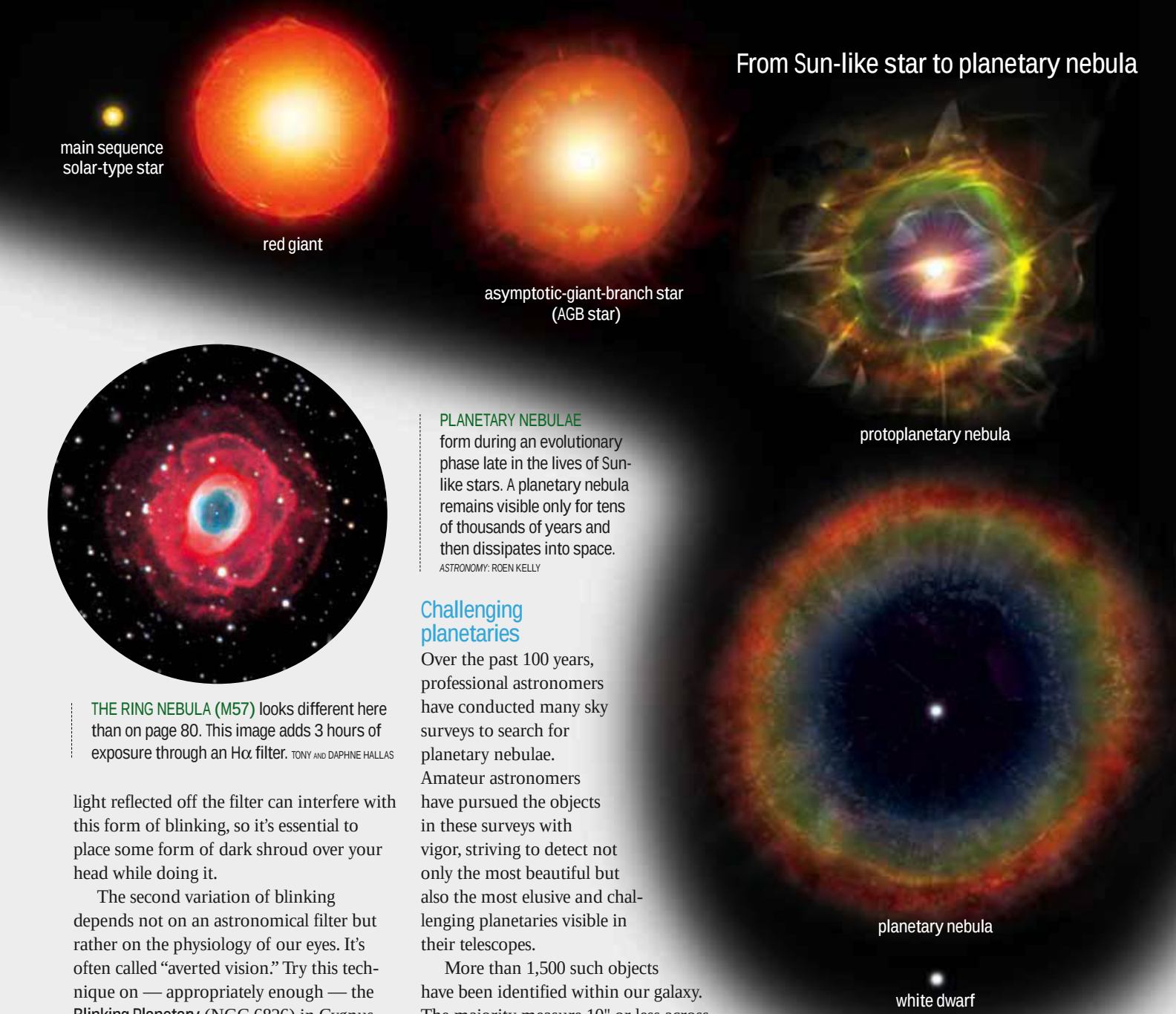
THE CAT'S EYE NEBULA (NGC 6543) in Draco requires a steady sky and high magnification to see detail. ADAM BLOCK

THE SATURN NEBULA (NGC 7009) in Aquarius was discovered by English astronomer William Herschel, discoverer of Uranus. ADAM BLOCK

PK40–0.1 in Aquila is a classically round planetary nebula. The color is due to interstellar reddening caused by dust clouds. ADAM BLOCK

THE BLUE SNOWBALL (NGC 7662) in Andromeda is noted for its vivid blue color, which is reminiscent of Neptune's. ADAM BLOCK

THE HELIX NEBULA (NGC 7293) in Aquarius is an easy binocular object and even has been spotted with the naked eye. ADAM BLOCK



PLANETARY NEBULAE form during an evolutionary phase late in the lives of Sun-like stars. A planetary nebula remains visible only for tens of thousands of years and then dissipates into space. *ASTRONOMY:* ROEN KELLY

THE RING NEBULA (M57) looks different here than on page 80. This image adds 3 hours of exposure through an Hα filter. TONY AND DAPHNE HALLAS

light reflected off the filter can interfere with this form of blinking, so it's essential to place some form of dark shroud over your head while doing it.

The second variation of blinking depends not on an astronomical filter but rather on the physiology of our eyes. It's often called "averted vision." Try this technique on — appropriately enough — the **Blinking Planetary** (NGC 6826) in Cygnus. The central star of this magnitude 8 planetary nebula shines at about 10th magnitude. The nebula disappears when you concentrate your view on the star, but look slightly away from the star, and the nebula reappears — bright enough to overwhelm the star's light. Dart your eye back and forth, in effect, blinking the planetary. Because most planetaries respond well to higher magnifications when atmospheric conditions allow, don't hesitate to change eyepieces while viewing each object. This will almost always change the view you experience — sometimes dramatically.

Doug Snyder *is the president of the Huachuca Astronomy Club of Southeastern Arizona. He also discovered comet Snyder (C/2002 E2) in 2002.*

Challenging planetaries

Over the past 100 years, professional astronomers have conducted many sky surveys to search for planetary nebulae. Amateur astronomers have pursued the objects in these surveys with vigor, striving to detect not only the most beautiful but also the most elusive and challenging planetaries visible in their telescopes.

More than 1,500 such objects have been identified within our galaxy. The majority measure 10" or less across. The largest known planetary — **Hewitt 1** — lies in Sextans and spans more than 2°. Recently, a team of astronomers detected an elliptical halo extending out to at least 6° by 9° from this object's center.

Not quite as challenging, but still difficult to locate, is **Pease 1**, a planetary nebula measuring only 1" in diameter located near the center of globular cluster M15 in Pegasus. Pease 1 is one of only four planetaries discovered within globular clusters. Of the four, Pease 1 is the easiest to root out from the surrounding star field. Several amateurs using telescopes with apertures as small as 10 inches have been successful in observing this evolved star, but to do so requires an OIII filter, detailed star charts, and a warehouse of patience.

Lots of choices

Amateur astronomers can locate many planetaries. Most occur near the galactic plane, with more toward the galactic center. As evidence of this, Sagittarius is home to 206 — or 18 percent — of all the planetary nebulae appearing in the *Strasbourg-ESO Catalog of Galactic Planetary Nebulae*. Scorpius is next with 104 (9 percent). Sixty-four of the 88 constellations contain at least one planetary. Observers — especially those with 8-inch and larger scopes — have their pick from this vast garden of pretty sights.

Tour Hubble's best shots of planetaries at www.astronomy.com/toc

In this region of the Moon's southern highlands, around the crater Janssen and the Rheita Valley, impact is the name of the game. /// BY ROBERT BURNHAM

Explore a lunar debris field

When the Moon is 5 or 6 evenings

old, sunlight falls across a tangled landscape in its southern highlands. This region appears complex, and most features are ancient, even by lunar standards. But the key to exploring such terrain lies in separating younger, fresher-looking features from the older, more subdued ones. The lunar crust, about 45 miles thick in the highlands, has been churned by impacts 20 miles deep or more, yet the region's visible surface is dominated by ejecta from just two impact basins. The older Nectaris basin is centered roughly 560 miles to the north of our target area, while the Imbrium basin, about 70 million years younger, is more distant. The asteroid that excavated the Nectaris basin struck 3.92 billion years ago, throwing a thick debris layer across part of this area.

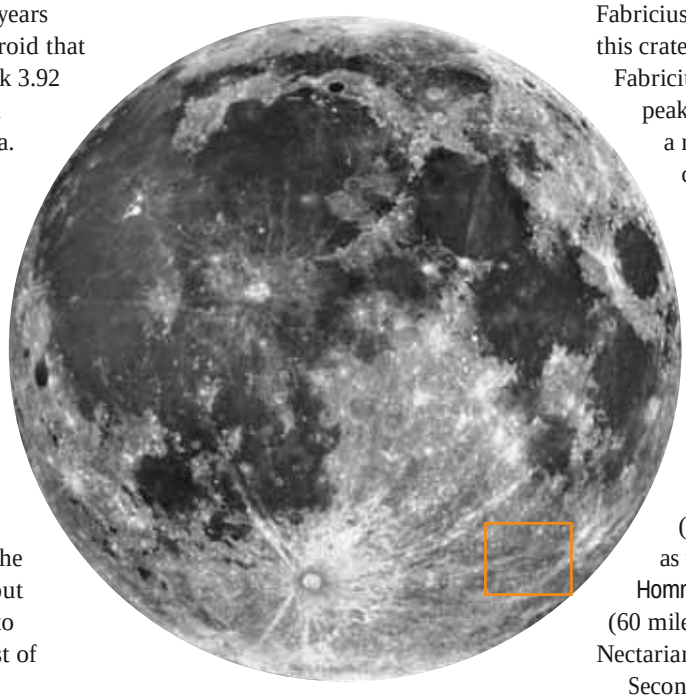
Notice the large crater **Janssen** (which is 120 miles wide). It formed before the Nectaris basin impact. Under a low sunlight angle, Janssen looks like two overlapping craters forming a hexagon shape.

A rumpled debris layer covers the northern half of Janssen's floor. This is part of the Janssen Formation, a slow-moving surge of debris from the Nectaris basin that flowed across the landscape before halting here. About half a mile thick, it reaches south to include the surface lying to the east of **Pitiscus** (51 miles).

By contrast, Janssen's southern floor is smoother, with intersecting rilles. Lunar geologists say this part of the floor was blanketed with ejecta from the crater **Fabricius** (49 miles). This crater has an estimated age of 1.2 to 3.2 billion years, younger than most other craters nearby. When the seeing is steady, use 100x to 250x to compare Fabricius with **Metius** (55 miles). Metius has the smoother floor, yet Fabricius' walls appear fresher, a token of this crater's relative youth. The floor of Fabricius has, in addition to its central peak, a curious semicircle. This may be a rampart at the foot of landslides coming from disturbed sections of the wall where craters adjoin.

If Fabricius is comparatively young, many of the larger grouped craters in the area — such as Pitiscus, **Vlacq** (55 miles), **Steinheil** (42 miles), and **Biela** (47 miles) — have less-detailed walls and are clearly older. Geologists think these are secondary impacts from Nectaris. (Metius likely belongs among them as well.) Still other large craters — **Hommel** (78 miles) and **Rosenberger** (60 miles), for example — are pre-Nectarian like Janssen.

Secondary cratering is repeated all over the Moon — indeed, on every solid surface in our planetary system. When an asteroid's impact creates a basin, chunks of surface debris shoot beyond the basin's



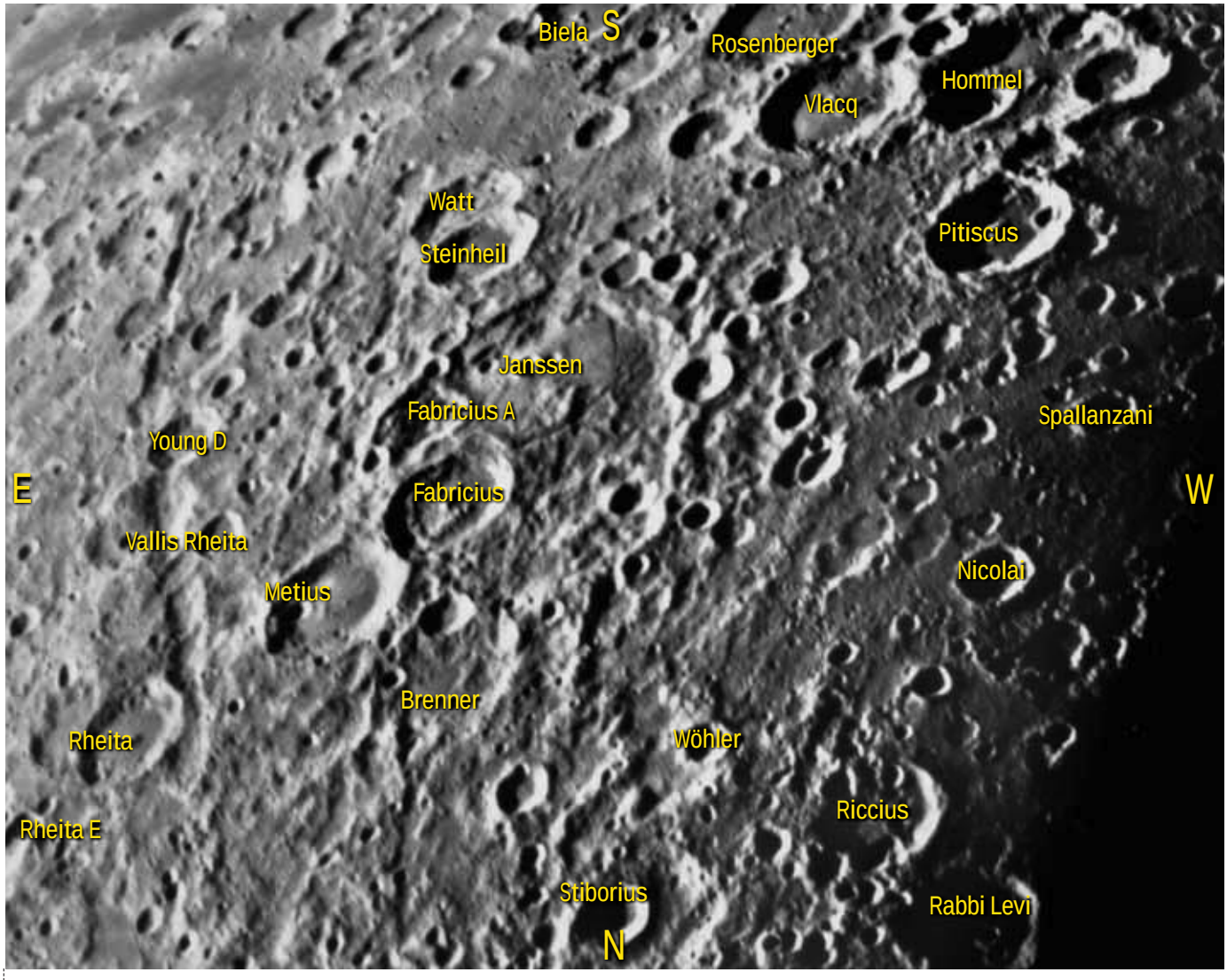
FIND VALLIS RHEITA AND THE CRATER JANSSEN with the help of this locator map. This image is oriented as you see the Moon in the sky, with north at the top. LICK OBSERVATORY

/// BEST DATES TO OBSERVE

Lunar sunrise and sunset are the best times to view the Moon because shadow detail is greatest then. The best dates to observe Janssen and Vallis Rheita for the next 3 months are listed below.

Lunar sunrise
Jan. 13–15, Feb. 12–14, March 14–16

Lunar sunset
Jan. 28–30, Feb. 27–March 1, March 28–30



OUR TARGET AREA lies in the Moon's southern highlands. South is at the top, mimicking the view through most telescopes. LUNAR AND PLANETARY LABORATORY

boundaries, creating a far-flung fabric of secondary impacts. Only the larger Nectaris secondaries remain because later cratering obliterated smaller ones.

Among the surviving secondaries is one of the Moon's more eye-catching features, the Vallis Rheita, or Rheita Valley. Some 300 miles long by 20 miles wide, it is the scar left after Nectaris debris hit. During steady seeing, 100x shows the valley has an uneven floor and irregular walls, the result of a chain of craters merging. South of the crater Young D (29 miles) lies more of the valley — or perhaps the scar of another secondary string that flew on a slightly different trajectory. The crater Rheita (44 miles), whose western wall juts into the valley, is itself of Nectarian age but slightly younger than the valley.

One odd, straight feature is easy to see at sunrise and sunset, but it's hard to ascribe its origin. Running north from Fabricius and Metius is an unnamed, west-facing scarp. This may be a fault line produced by the seismic shaking that followed the Nectaris basin impact.

Seventy million years after the Nectaris basin formed, a much bigger impact formed the Imbrium basin 1,500 miles to the northwest. Imbrium ejecta blanketed a few features here, and the "splash" of molten rock created many other craters.

An example is the S-shaped chain of craters, all 5 to 10 miles across, starting at the southeast rim of the ruined crater Riccius (44 miles). The chain turns south, then west, then south again to end west of Nicolai (26 miles). These craters are secondaries from the Imbrium basin impact. Other, similar-size craters nearby are probably also Imbrium secondaries.

Across the scene weave intersecting lines of craterlets. Those trending roughly north-south show up clearly under a rising or setting Sun, while others have orientations toward other points on the compass. Some point obviously to basins, while others remain enigmatic.

A "geological prehistory" threads through this region but is hard to discern even with the help of spacecraft data — let alone see from Earth. At the time of the Nectaris impact, this region was already scarred by two more ancient basins, the Mutus-Vlacq and Australe basins, but the extent of these basins is difficult to see.

The lunar highlands are difficult to interpret fully — so many impacts, so much reworking. But they offer no end of features for backyard astronomers to explore with their telescopes.

Robert Burnham, *a senior editor of* Astronomy, *is the author of* Exploring the Starry Sky *(Cambridge University Press). He is working on a new book,* The Moon: a Telescopic Guide *(CUP).*

PROFILE

What began as a hobby turned into a career for Fred Espenak, a NASA astrophysicist who chases eclipses around the globe. /// BY BOB BERMAN

Meet "Mr. Eclipse"

You're thinking about traveling to the Mediterranean to view next year's total solar eclipse but don't know exactly where to go. Or maybe you'd like to find out how long you or your children must wait before an eclipse darkens your hometown. Where do you turn? It's always the same source, the same person: Fred Espenak.

THE SUN'S CORONA is highlighted in this composite image of the July 11, 1991, total solar eclipse over San Jose del Cabo, Baja, Mexico. Totality lasted nearly 7 minutes. FRED ESPENAK

An astrophysicist at Goddard Space Flight Center in Greenbelt, Maryland, Espenak is a renowned expert at tracking and predicting eclipses. In fact, his eclipse projections have become the gold standard for amateurs and professionals alike. And for more years than most of us can remember, he's been a behind-the-scenes character in eclipse comedies and tragedies around the world.

For example, one amateur proudly proclaimed to his travel group a day before the 1991 Baja total solar eclipse that he had rented a car to travel 40 miles down a desolate highway in order to see 15 extra seconds of totality. According to Espenak's detailed maps, published by NASA, the group's hotel site would enjoy a lengthy 6 minutes and 25 seconds of totality, but the slightly better 6:40 lurked an hour to the northeast. However, when the eclipse was over and the group was reminiscing about the glory, that man and a companion returned with downcast faces. Their site had been cloudy.

Bob Berman *is a contributing editor of* Astronomy *who writes "Bob Berman's Strange Universe" each month. His previous feature was "The outsider" in the October 2003 issue.*

They hadn't seen a thing. If only they hadn't possessed Espenak's tempting, meticulously detailed maps, they would have stayed put.

Espenak tells of an opposite experience during the 1980 eclipse in Kenya. "[Our tour group] set up in a soccer field at a plantation, but clouds moved in because the partial phase had produced cooling temperatures. Soon it became 90-percent overcast. So we jumped into the bus and chased a hole, then stopped and leaped out to set up our scopes as totality began. Unfortunately," he recalls, "the slow-moving clouds covered the Sun just before the end of totality. So I desperately ran down the road as fast as I could — and managed to keep the eclipsed Sun in the hole. I was the only one in our group to see the diamond ring at third contact. It gave new meaning to the expression 'eclipse chasing.'"

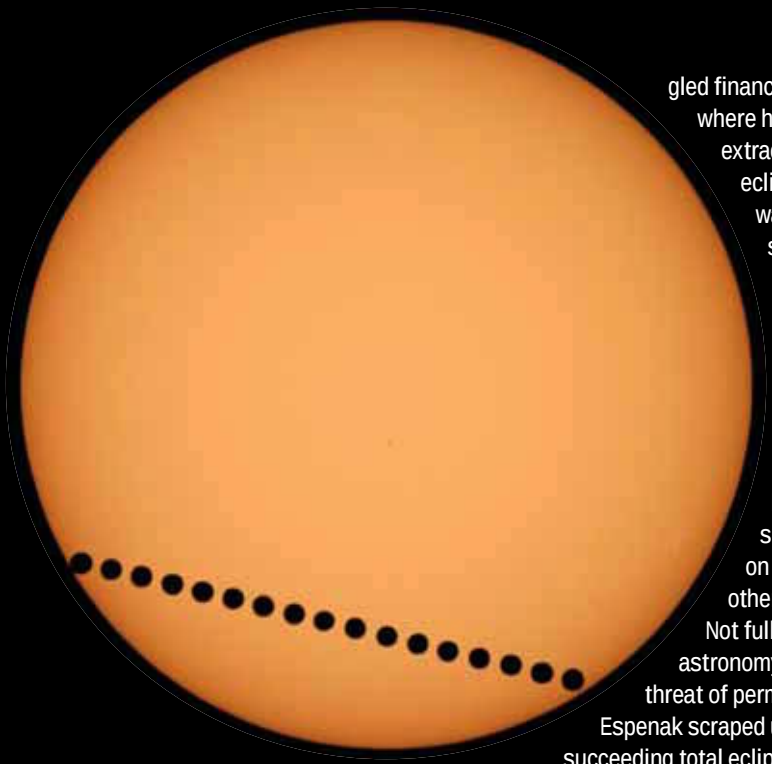
Eclipse fever

Espenak grew up on Staten Island, part of New York City that still had relatively dark skies. He looked through a telescope for the first time when he was 8 and quickly became "a science geek." He was an avid amateur astronomer in high school, with a focus on observing rather than telescope building. The partial solar eclipse of 1963 stoked his passion so that nothing would stop him from driving 600 miles to see his first total eclipse March 7, 1970, in North Carolina. Under perfect, cloudless skies, he observed what was destined to be the final totality in the eastern United States for the next 47 years.

Espenak did many things wrong that day. He used neutral-density filters to cut down the Sun's light during the partial phases (a potentially retina-damaging no-no), then fumbled around with torn film in his camera and missed much of totality as a result. But he had caught Eclipse Fever. Espenak had discovered the expensive addiction that has plagued so many innocent, unwary

CRUISING IN A DC-9 over Joensu, Finland, Espenak snapped this photo of a total solar eclipse July 20, 1990. FRED ESPENAK

FRED ESPENAK has witnessed 18 total solar eclipses, and his eclipse-path predictions are the field's gold standard. CHRIS GUNN



THE TRANSIT OF VENUS June 8, 2004, was captured in this composite of 17 images taken at 20-minute intervals from Sounion, Greece. The next transit occurs June 6, 2012, and will be visible in its entirety from northwestern North America and eastern Asia. FRED ESPENAK

amateur astronomers: the craving to experience the Moon's shadow again and again.

He knew a long totality was coming in 1991, but it was too long to wait! So he drove north to Quebec for the 1972 event, only to be clouded out. The next year, Espenak struggled financially to get to Africa, where he managed to see the extraordinarily long 6-minute eclipse. Although the view was subdued by hazy skies, this was hardly a discouragement for someone who was seriously hooked.

An astronomy career

Around this time, he began studying physics at Wagner College on Staten Island with other scientist-hopefuls. Not fully discouraged from an astronomy career despite the threat of permanent poverty, Espenak scraped up funds to see each succeeding total eclipse. He was clouded out in 1977, saw a total eclipse in Winnipeg 2 years later through thin, high clouds, and went back to Africa in 1980 for that marathon hole-peeking scramble.

By then, he'd finished graduate school and landed a job at Goddard, where he grew intrigued with a new aspect of eclipses — how computers could plot and predict their tracks with unprecedented accuracy. Using FORTRAN and the Besselian elements (the standard method of determining eclipse circumstances), he tweaked and adjusted programs until he found he could produce maps and charts for upcoming eclipses that were better than anything previously published. NASA agreed, and for the past 10 years or so, Espenak's data have been published on-line at *sunearth.gsfc.nasa.gov/eclipse/eclipse.html*, available to everyone at no charge.

He has branched out to other areas of observable phenomena, which is why so many people clicked on his invaluable transit-of-Venus data last year. (Espenak calculated the local circumstances for about a thousand places.) He says the transit was not as spectacular visually as solar totality, but he was excited nonetheless. "This was an ideal public outreach and education tool," he explains, "even if it was just a minor footnote without the incredible scientific importance it had back in the 19th century," when it was used to calculate the Sun's distance.

A monumental project

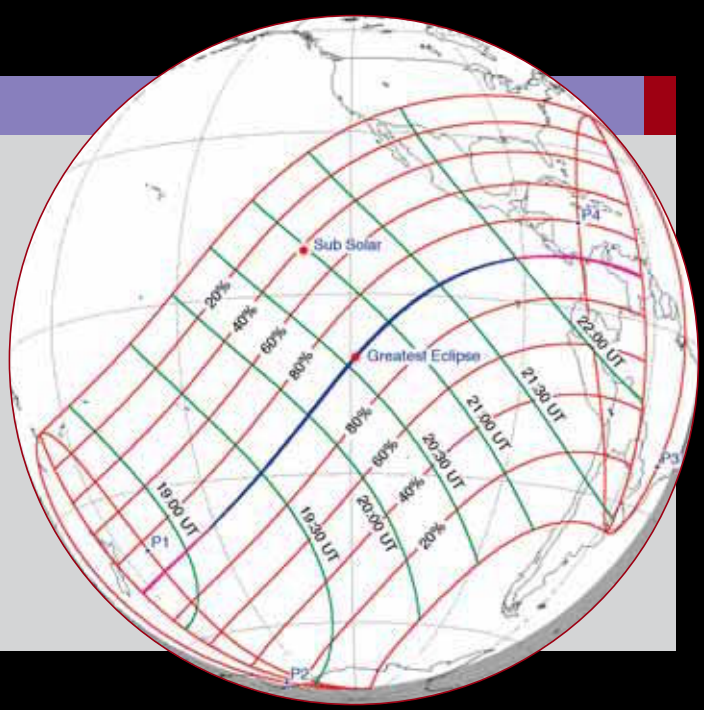
Predicting is indeed Espenak's passion — he's spent much of the last 2 years working on a comprehensive world atlas of solar-eclipse paths. He just completed the herculean task of preparing maps for every part of the globe divided into 20-year periods from 1000 B.C. to A.D. 3000. Just last summer, he posted the charts on the NASA web site mentioned above, so they are available to anyone who wants to look into the past or future.

It's fascinating, all right. Considering that each spot on Earth averages one total eclipse each 360 years, it's fun to see those places where the laws of chance momentarily broke down to deliver two, or even three, totalities in the space of just a few years.

/// SOLAR ECLIPSE IN APRIL

Join Fred Espenak, *Astronomy* editor Dave Eicher, and astronomer Jay M. Pasachoff on a cruise to the Galapagos Islands for the April 8 total solar eclipse. Enjoy 2 weeks aboard the M/ V Galapagos Legend, with stops to explore the islands and see the animals. This group of volcanic islands, which lies on the equator some 500 miles west of Equador's coast, is home to exotic wildlife, including giant tortoises and Galapagos penguins.

On eclipse day, you'll experience approximately 34 seconds of totality from the ship's deck, about 680 miles (1,100 km) west of the Galapagos. The trip runs March 31–April 14. For more information, contact Jen Winter at Astronomical Tours, jen@astronomicaltours.net, or visit www.astronomy.com/tours. — *Laura Baird*



TOTALITY WILL OCCUR over the Pacific Ocean during the April 8, 2005, solar eclipse. This map, created by Fred Espenak for NASA, charts the Sun's path and eclipse-viewing areas. F. ESPENAK, NASA/GSFC

These are towns whose residents must regard total solar eclipses as almost routine. Then there are the bad-luck cities that get no totalities for over a thousand years!

Globetrotting

Espenak himself seems to have entered a viewer-friendly period after those first frustrating mostly-cloudy events. In 2003, he witnessed his 18th solar totality, in Antarctica. No longer does he have to scrape together funds for his adventures because his fare is usually covered by various organizations in exchange for giving lectures. Better still, he met his fiancée, Pat, a retired chemistry teacher, at an eclipse in India.

And he still finds eclipses as magical as ever. "Each eclipse is different," Espenak says, "The corona is so dynamic; it changes from hour to hour. So, *of course*, every totality will be unique. And more than that, you can use eclipses as launch vehicles to take you to different cultures around the world."

He remains amazed at how much superstition still surrounds eclipses, and how people in some parts of the world continue to ascribe supernatural causes to them. One common multicultural belief, for example, is that eclipses are especially injurious for pregnant women because they can harm the unborn child.

In the shadow

The spirit of human competition manages to creep into even such otherworldly experiences as solar totalities. Like many eclipse fanatics, Espenak keeps track of his cumulative time in the Moon's shadow. (It's 44 minutes, as of now.) Clearly, he's unconcerned with rumors that the shadow can cause mental illness.

In fact, he's obviously trying to join the "1-hour club," whose worldwide members probably number fewer than those who have reached the summit of Mount Everest. Espenak needs another 16 minutes, and he could gain 19 if he attends and gets clear weather for the next five totalities.

In case you're tempted, they're a 42-second affair in the southeastern Pacific April 8, 2005; a wonderful 4-minute African, Mediterranean, and Turkish eclipse March 29, 2006; a challenging 2½-minute Siberian and Chinese totality August 1, 2008; the century's longest eclipse, a 6½-minute marathon over China and the western Pacific July 22, 2009; and a 5-minute show over the South Pacific July 11, 2010.

If you travel to any of these destinations to view an unrivaled display of celestial geometry, chances are, "Mr. Eclipse" will be there also. If, on the other hand, you want to know when a solar eclipse will darken your hometown, you need only turn to the marvelous maps of Fred Espenak.

Fred Espenak recounts his favorite eclipses at www.astronomy.com/toc

THE TOTAL LUNAR ECLIPSE January 9, 2001, plunged the Moon into Earth's dark umbral shadow, making our satellite appear red. This image was taken from Athens, Greece. FRED ESPENAK

FRED ESPENAK travels the world observing and photographing eclipses. For the August 11, 1999, total solar eclipse, Espenak traveled to Lake Hazar, Turkey, where this photo was taken. PATRICIA TOTTEN

A TOTAL SOLAR ECLIPSE occurred October 24, 1995, over Dundlod, India. Totality was a brief 40 seconds because the Moon appeared only 1.1 percent larger than the Sun. FRED ESPENAK

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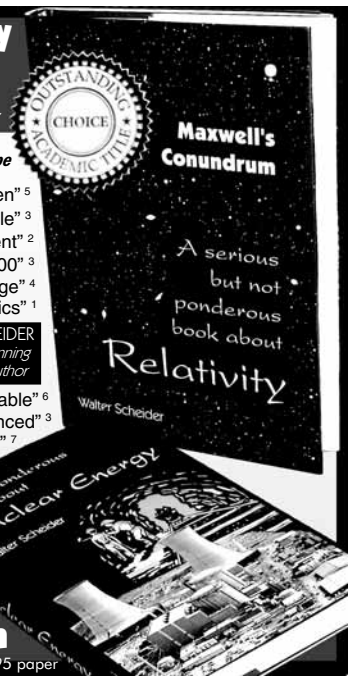

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Astronomy magazine

Designed for portability and ease of use, this reflector features more than 3 inches of aperture. /// BY PHIL HARRINGTON

Backpack this scope

These days, telescopes come in a variety of shapes and sizes. No matter which astronomical niche you're interested in, there seems to be a telescope to fit your needs. That is, except for one. What about a telescope for the youngest astronomers? Even the smallest refractors and reflectors are usually too large and too heavy for small-fry stargazers to handle, which means they either have to rely on an adult to set up the telescope for them or do without.

To help fill this gap, Celestron recently introduced the 3.1-inch f/6.9 ExploraScope, a miniature Newtonian reflector poised on a unique tabletop base. The ExploraScope weighs only 5 pounds and measures 14" long, making it small and light enough for a 7-year-old to carry. The ExploraScope's gourd-like shape is reminiscent of Edmund Scientific's venerable Astroscan, which can trace its own roots to amateur telescopes made more than 30 years ago.

Overview

The ExploraScope's optics are enclosed in a white, molded-plastic tube assembly. Two wing-like bulges serve as grips for either holding or guiding the telescope. A carrying strap is attached between the wings. Realizing a conventional altitude-azimuth or equatorial mount would be too cumbersome for kids, Celestron placed the ExploraScope on a small, concave base. This design lets users aim the telescope in any direction simply by pointing. No axes need to be negotiated, and no screws lock or unlock. Just point the telescope, and let it go. Users who prefer a more conventional mount will find an adapter included for attaching the instrument to a photo tripod. Be sure to check the adapter connection, as I found it would work its way loose unless it was tightened down firmly.

The ExploraScope comes with a 12.5mm eyepiece already mounted in the telescope's cleverly designed helical focuser. The eyepiece threads into a collar that travels up and down a track inside the drawtube as an observer turns the black-plastic focusing ring. The eyepiece magnifies 44x. The ExploraScope provides a right-side-up view by employing a built-in lens at the focuser's base. Focusing is smooth, without binding or dead spots.

The ExploraScope is designed to let adult users collimate both the primary and secondary mirrors. To adjust the primary, pop off three plastic plugs located at the bottom of the tube assembly. Inside are three Phillips screws that adjust the main mirror.

THE EXPLORASCOPE'S FOCUSER is a knurled, black ring located below the eyepiece. The front protective cover slides into place easily and keeps dirt out. *ASTRONOMY*: WILLIAM ZUBACK

Another trio of Phillips screws allows adjustment of the secondary mirror, which is held in the tube by a three-vane spider mount. The ExploraScope's instruction pamphlet includes some rudimentary instructions on aligning the telescope's optics, but if you're unfamiliar with collimation, seek a helping hand from an experienced amateur astronomer.

Setup's a snap

The ExploraScope is ready to use right out of the box — no assembly is required. Just place the telescope in its base on a picnic table or other sturdy surface, and it's set. For the test, I restricted my explorations to objects kids would be interested in viewing, such as the Moon and bright planets.

Initially, I found images were not as crisp as in some other small, inexpensive telescopes I've used. Removing the screw-in eyepiece and looking into the focuser revealed both mirrors were slightly out of collimation. Once they were aligned properly, image sharpness improved somewhat but still left something to be desired. Part of the problem lies with the ExploraScope's inexpensive eyepiece, and the inverter lens in the base of the focuser may be responsible for the remaining lack of sharpness.

That leads to one of my disappointments with the ExploraScope. Although I like the focuser's design, it's just a little too small. The ExploraScope's eyepiece looks like it has a standard 1¼" barrel that's threaded for filters. But it's not. It turns out the eyepiece barrel measures only about 1.2 inches, which means the focuser's drawtube is 0.05" too small to accept 1¼" eyepieces. That's really a shame because images could be improved by substituting even an inexpensive Plössl eyepiece. A 6mm Kellner eyepiece, which yields a magnification of 92x and which is sized for the ExploraScope, is available from Celestron dealers for $20.

CELESTRON'S EXPLORASCOPE is a great first telescope for young astronomers.

ASTRONOMY: WILLIAM ZUBACK

THE EXPLORASCOPE'S TABLETOP BASE is included and provides a stable platform for observing. *ASTRONOMY*: WILLIAM ZUBACK

Under the sky

When I pointed the ExploraScope at the Moon, I saw a wealth of surface features, including the central peaks of the craters Tycho and Copernicus. The Straight Wall was plainly visible, as were countless small craters. Of the planets, Venus' phase was evident, as were Jupiter's four Galilean moons and Saturn's rings. I could make out a hint of Jupiter's two equatorial belts, but I couldn't see the Cassini Division in Saturn's rings.

I also visited several bright deep-sky objects. While observing them, I measured the eyepiece's true field of view at approximately 0.9°, close to Celestron's stated value of 1°. The Pleiades (M45) cluster put on a nice show. The Orion Nebula (M42) showed its characteristic shape along with the four stars of the Trapezium buried inside. Several bright globular clusters — M13, M15, and M92 — were apparent, although the small aperture couldn't resolve individual stars. Finally, some well-known double stars, such as Albireo (Beta [β] Cygni), were split easily.

Observing quickly revealed the biggest shortcoming of a scope like this: It's difficult to aim. The lack of a finder scope meant I had to scan back and forth until the target crossed the field of view. The Moon's glare made it easy to acquire, but even Venus, blazing brilliantly in the morning sky, took some effort to locate.

A LOOK INTO THE EXPLORASCOPE reveals a secondary mirror that can be collimated by adjusting three screws. *ASTRONOMY*: WILLIAM ZUBACK

Phil Harrington *is the author of the new observing guidebook* Star Watch, *which is published by John Wiley & Sons.*

Life with the ExploraScope improved after I attached a small, red-dot, single-power finder to the tube, and I'd recommend anyone buying the telescope do the same. Keep in mind, however, that because the tube is tapered, you'll need to shim the finder (I used a washer) in order to make it parallel to the telescope's optical axis.

You try it

Of course, Celestron was not trying to appeal to *me* when it introduced the ExploraScope — the company designed the telescope for kids. With that in mind, I loaned the ExploraScope to my brother Steve and his family. He and his wife, Ann, have two kids: Lilia, who is 8, and Dan, 4. None has any working knowledge of telescopes (I just didn't rub off on Steve during childhood), which probably makes them typical of those who will purchase ExploraScopes. What did they think of it?

After using it during both the day and night, they came away with a few interesting points. Lilia especially liked being able to carry the telescope herself using the shoulder strap, and she thought setup was a snap. But the simple design of the telescope's base also worked against it during use. Because there is no way to lock it in place, they found that it was easy to throw the telescope off its target when changing observers. Like many adults who are unfamiliar with viewing through an eyepiece, the kids grabbed the scope when viewing. And unless focusing was done gently, it threw off the telescope's aim.

Like me, the family members had one problem: aiming the telescope. In the end, they entertained themselves by scanning the sky back and forth rather than selecting targets, save the Moon. Although there is no suggested minimum age on the box, I'd surmise the range is 7 to 10.

/// PRODUCT SPECIFICATIONS

CELESTRON EXPLORASCOPE
- 3.1-inch (80mm) Newtonian reflector
- 550mm focal length at f/6.9
- 12.5mm eyepiece included
- Carrying strap included
- True field of view: 1°

Length/weight:
14 inches/5 pounds

Street price:
$60 to $70

CONTACT INFORMATION:
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A few parting remarks

Most results from testing the ExploraScope were positive. On one hand, Celestron produced a lightweight telescope kids can carry and set up on their own. Images are reasonably sharp and easy to focus. On the other hand, the telescope lacks a finder scope and is easily knocked off target because it's held in place by gravity alone.

While the ExploraScope has some drawbacks, it is still better suited for young astronomers than any department-store telescope. As my friend Geoff Gaherty put it, "many small telescopes are really toys in disguise, but Celestron's ExploraScope is actually a telescope disguised to look like a toy." So, parents, if a small, portable telescope is on your child's gift list, the ExploraScope just might be right for him or her. A

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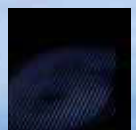

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Where is China's space program going?

China's Space Program — From Conception to Manned Spaceflight

Brian Harvey, 349 pages, Springer, New York, 2004; ISBN 1–85233–566–1; paperback, $34.95

When China became the third nation in history to fly a man into orbit aboard its own spacecraft in October 2003, the rest of the world took notice. But China has been carrying out impressive space feats for more than 3 decades. The flights may have numbered far fewer than those launched by the United States and Russia, but they demonstrated impressive — and generally unappreciated — levels of technology and reliability.

In this new book, Irish space author Brian Harvey updates an earlier book, *The Chinese Space Programme*, (Praxis, 1998). The updates include not only events that have occurred since the earlier work was published, but Harvey also used the flood of historical material becoming available to fill in gaps in knowledge.

Although China remains a secretive society in principle, the authorities are releasing far more information now than the Soviet Union did at the beginning of the Space Age in the 1950s. Moreover, numerous unofficial, but generally reliable, information sources have emerged as the country becomes more capitalist.

As a result, Harvey's book gives any space-flight enthusiast a thorough overview of China's space activities while comparing them to other nations' efforts. What's more, Harvey has succeeded in an even greater challenge: collecting disorganized and unrelated information and formulating it into coherent chapters that address themes, activities, and intentions in a lucid, logical sequence. This book goes well beyond cataloging what it covers.

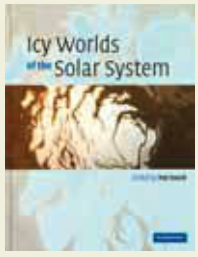
It has good stories, too. Harvey's description of the early years of the Chinese program, when it was bedeviled by material shortages and political interference, is as dramatic as any other space-development saga in the world.

He also makes excellent use of new biographical material about the father of the Chinese program, Tsien Hsue Shen. Tsien was born in China in 1911 and educated at Caltech, where he studied under Theodore von Kármán and helped found the Jet Propulsion Laboratory.

In 1956, Tsien went back to China after being arrested during the McCarthy witch-hunt period; he became China's Wernher von Braun. (For unexplained reasons, Harvey uses the old-style spelling of Tsien's name, not the new form, which is Qian Xuesen.) No spy novel has a more convoluted plot than this person's real life.

Harvey achieves a good blend of engineering descriptions and human-interest stories. Equally important, he gives the reader helpful guidance regarding reliability by describing how information on the Chinese program comes to light while other material concerning it remains buried in secrecy.

Finally, Harvey uses obscure Chinese reports and speeches to map out the future options for this nation, now a major player in outer space. Driven as it is by a prickly sense of national pride, China may well come to dominate some phases of human space exploration in the years ahead. If that comes to pass, this book will have told you how it happened. — JAMES OBERG, *a former NASA mission controller, keeps an eye on various countries' space programs from Houston. His latest book is* Star-Crossed Orbits: Inside the U.S.-Russian Space Alliance. A



Icy Worlds of the Solar System

Pat Dasch, editor, 202 pages, Cambridge University Press, New York, 2004; ISBN 0–521–64048–2; hardcover, $45.

Seven chapters written for general readers by planetary scientists deal mostly with places so cold the local "rock" is water ice. But, as the authors explain, both the Moon and Mercury have ice deposits as, of course, do Earth and Mars. The bulk of the coverage, however, looks at worlds from roughly Jupiter's orbit outward, including comets. These are bodies where ice of one substance or another dominates the surface geology. One important caution: Anyone looking for background on Saturn's big moon Titan will find little because this intriguing world was barely understood when the book was being written.

The Beginner's Observing Guide, 5th edition

Leo Enright, 196 pages, Royal Astronomical Society of Canada, 2004; ISBN 0–9689141–5–2; paperback, $19.95.

[w] www.store.rasc.ca

This basic guide helps newcomers get oriented in skywatching. It contains six black-and-white sky maps that show the main stars and constellations. It also has nearly 20 short chapters covering topics such as buying a telescope, taking astrophotos, observing the solar system, watching eclipses, and dealing with light pollution. (Deep-sky objects are covered in the bimonthly sky-map descriptions.) The book concludes with a good set of references, a glossary, and the answers to about a dozen common astronomy questions.

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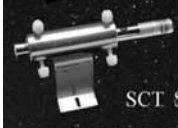

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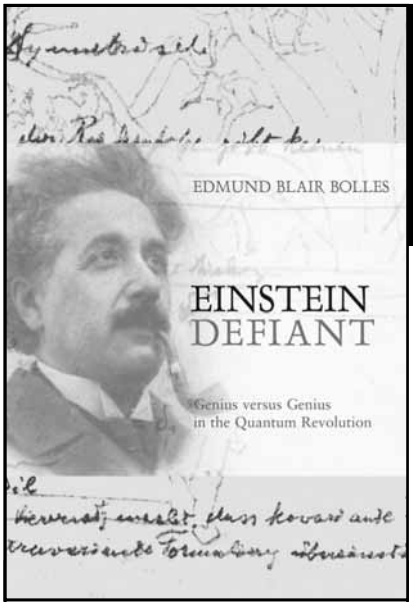

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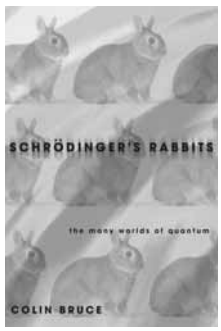

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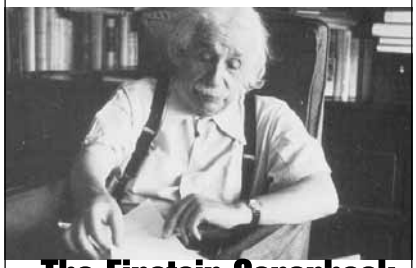

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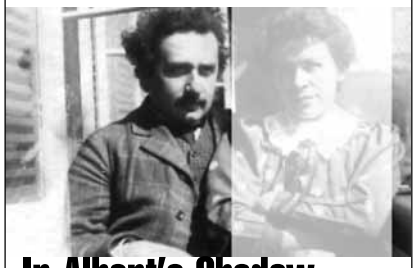

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EINSTEIN'S CENTURY

BOOKS — Banesh Hoffmann's *Albert Einstein: Creator and Rebel* (Viking, New York, 1972) is a biography that has some discussion of Einstein's scientific work. A book that delves deeper into the science is Abraham Pais' *Subtle Is the Lord* (Oxford University Press, New York, 1982).

The Einstein Scrapbook by Ze'ev Rosenkranz (Johns Hopkins University Press, Baltimore, 2002) is a photobiography organized by theme and written by the curator of the Einstein archives at The Hebrew University of Jerusalem.

For those who want to tackle general relativity, start with *Spacetime and Geometry: An Introduction to General Relativity* by Sean M. Carroll (Addison Wesley, San Francisco, 2004).

WEB — Explore the Einstein archives at *www.albert-einstein.org*. It offers scanned manuscripts, most of which are in the original German.

Caltech has the Einstein Papers Project at *www.einstein.caltech.edu*; it aims to publish a translation of everything Einstein wrote. Caltech likewise has scanned photos, mostly from Einstein's several visits to Pasadena in 1930–32. Start at *archives.caltech.edu/photoNet.html*, and click on the Einstein link.

The American Institute of Physics has an on-line exhibit at *www.aip.org/history/einstein* plus a photo archive at *www.aip.org/history/esva*; click on the Einstein link.

For a multi-page tour of relativity, including on-line (java) demos and animated GIF images, see *archive.ncsa.uiuc.edu/Cyberia/Expo/numrel_nav.html*.

CASSINI TARGETS TITAN

ARTICLE — Read Richard Talcott's "Cassini reaches Saturn" (*Astronomy*, October 2004) for more on the spacecraft's historic arrival at the ringed planet.

WEB — NASA's page on the Cassini orbiter is at *saturn.jpl.nasa.gov/index.cfm*. The European Space Agency's site for the Huygens probe is at *sci.esa.int/science-e/www/area/index.cfm?fareaid=12*.

ASK ASTRO

WEB — Learn about the Voyagers' missions at *voyager.jpl.nasa.gov/mission/interstellar.html*. Track the Voyagers and other spacecraft on-line with the National Space Science Data Center's Helio Web tool at *nssdc.gsfc.nasa.gov/space*.

SEE A STAR DIE

BOOKS — A beautiful and informative book about planetary nebulae is *Cosmic Butterflies* by Sun Kwok (Cambridge University Press, New York, 2001).

Observers will be interested in *Planetary Nebulae: A Practical Guide and Handbook for Amateur Astronomers* by Steven J. Hynes (Willmann-Bell, Richmond, Virginia, 1992). Hynes lists 1,340 objects and includes 253 finder charts.

WEB — Doug Snyder's planetary-nebula page at *www.blackskies.com/index1.html* is a treasure trove of information. A great place for advanced planetary-nebula observers is Eric Honeycutt's site at *www.icplanetaries.com*.

EXPLORE A LUNAR DEBRIS FIELD

WEB — *Lunar Orbiter Photographic Atlas of the Moon* by David Bowker and J. Kenrick Hughes, published by NASA in 1971, has long been out of print, but an on-line version is available at *www.lpi.usra.edu/research/lunar_orbiter/index.html*.

MEET MR. ECLIPSE

BOOK — *Totality: Eclipses of the Sun*, 2nd edition, by Mark Littman, Ken Willcox, and Fred Espenak (Oxford University Press, New York, 1999) addresses all aspects of eclipse science and observing.

WEB — Espenak's personal home page, *www.mreclipse.com*, covers eclipse-photography techniques in detail and displays more of his stunning images. A

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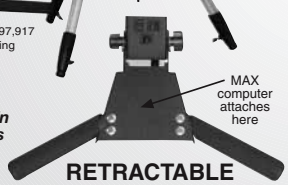

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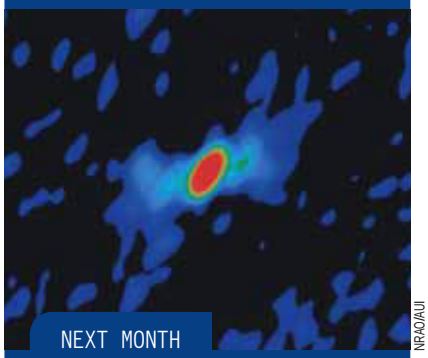

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03.09.05–03.13.05

The Kisatchie Star Party (KSP), based

in the pine-covered hills of central Louisiana, is celebrating its fifth year. Relatively young, the KSP already has earned a reputation as a top early-season star party and is sure to draw more observers than previous years. Hosted by the

AS RED LIGHTS GLOW during late winter and early spring star parties, some observers will shake off the winter cobwebs and reacquaint themselves with gems of the night sky. EMERY HILDEBRAND

Baton Rouge Astronomical Society and held in the Kisatchie National Forest, the star party is blessed with isolation. Natchitoches, both the nearest town and source of light pollution, is a 45-minute drive from the site, ensuring dark skies.

Given the remote location, most attendees will stay on the ample campgrounds, but motels are located close to town.

The setting offers a multitude of non-astronomical activities, including bird-watching, hiking, fishing, or canoeing the nearby placid streams or rapids.

For more information, e-mail kisatchie@cox.net; web site, *www.bro.lsu.edu/bras/kisatchie.html*.

THROUGH MAY 2005

Solar Fireworks

Newark Museum, Newark, New Jersey. Designed by astronomers at the Newark Museum and the New Jersey Institute of Technology, this exhibit features hands-on activities and information on the Sun's composition. For more information, visit *newarkmuseum.org/planetarium*.

THROUGH MAY 2005

SPACE: A Journey to Our Future

Museum of Science and Industry, Tampa, Florida. This touring exhibit provides a hands-on, educational experience for all ages. Visitors can handle actual lunar rocks, explore a simulated International Space Station, and take the helm to land a virtual lunar module. For more information, visit *www.spaceevent.com*.

02.02.05–02.06.05

Deep South Texas Stargaze

Escondido Ranch, McMullen County, Texas. Hosted by the Kingsville Astronomical Society, this gathering is held under nearly 7th-magnitude dark skies. Climate-controlled bunkrooms with showers are available as well as camping and RV sites. In addition to observing,

there will be speakers, workshops, door prizes, and contests. For more information, visit *www.geocities.com/kingsville_astronomical_society*.

02.04.05
Far Out Friday
Adler Planetarium and Astronomy Museum, Chicago. On the first Friday of every month, the Adler hosts an evening of astronomy-related fun, including observing, lectures, and tours of the facilities. For more information, visit *www.adlerplanetarium.org*.

02.09.05–02.13.05
Orange Blossom Special Star Party
Alafia River State Park, Lithia, Florida. The new site has been entirely reserved for star-party attendees. For more information, e-mail dnefarr@msn.com; web site, *home1.gte.net/hoffmanc*.

03.05.05
Tri Star
Guilford Technical Community College, Jamestown, North Carolina. Cosponsored by the Cline Observatory and Greensboro Astronomy Club, this event features speakers, prizes, and vendors. For more information, e-mail trenglish@gtcc.edu; web site, *technet.gtcc.cc.nc.us/comserv/cline*.

03.10.05–03.12.05
Mid-Florida Star Gaze
Kye's Star Farm, near Venus, Florida. The Astronomical Society of Palm Beach will host this event. The site is based away from light pollution, high winds, sand, and the salty ocean spray. Attendance is limited, so submit your registration early. For more information, visit *www.palmbeachastro.org*.

03.13.05–03.15.05
South Pacific Star Party
Wiruna, near Ilford, New South Wales, Australia. Hosted by the Astronomical Society of New South Wales, this site offers great dark skies. The location, featuring many species of exotic birds, wombats, kangaroos, and other wildlife, is a nature-lover's paradise. For more information, visit *www.asnsw.com/spsp*.

04.06.05–04.08.05
International Dark-Sky Association Annual Meeting
Hilton Hotel, Tucson, Arizona. This year's conference will discuss present and future light-pollution issues, including human health and ecology. For more information, visit *www.darksky.org*.

04.06.05–04.09.05
Mid-South Star Gaze
Rainwater Observatory, near French Camp, Mississippi. Designed for anyone interested in learning about astronomy, this gathering will feature lectures and informal day and nighttime observing sessions. For more information, e-mail info@rainwaterobservatory.org; web site, *www.rainwaterobservatory.org/stargaze*.

04.08.05–04.10.05
Spring Equinox Star Party
Kelling Heath, Norfolk, United Kingdom. Organized by the Loughton Astronomy Society, this star party is held at a particularly dry site for the region. When not solar-observing, you can visit one of the many museums in greater Norfolk. For more information, e-mail info@starparty.org; web site, *www.starparty.org*.

04.16.05–04.17.05
Northeast Astronomy Forum and Telescope Show
Rockland Community College, Suffern, New York. This annual gathering features observing, workshops, lectures, and exhibitors. For more information, visit *www.rocklandastronomy.com*.

CONTACT INFORMATION
Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our on-line calendar.

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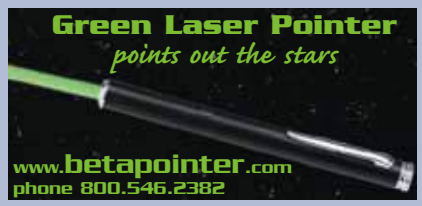

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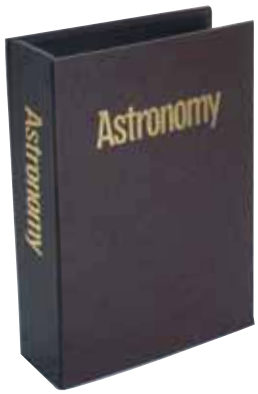

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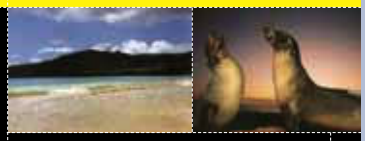

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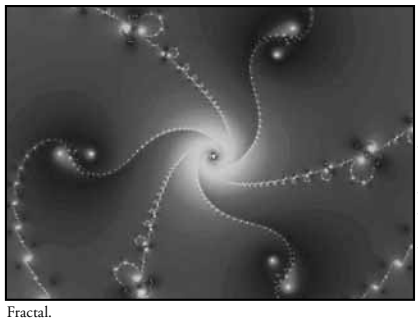

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Star trails /// North America Nebula /// Planetary nebula M76 /// Spiral galaxy NGC 7331
The Sun in Hα light /// NGC 6781 /// Globular cluster M10 /// Crater Posidonius

CAPTURING STAR PATHS AS EARTH TURNS

Star trails

Some of the most pleasing astrophotographs are also the easiest to produce. To create star trails, for example, just mount a camera on a sturdy tripod and open the shutter for a chosen length of time. Film cameras are still the preferred instrument for this type of photography. If you use a digital camera, be certain it has the capability to take a long timed exposure. A general rule is that the brighter your sky, the shorter your exposure should be. In a true-dark sky, you can make exposures up to several hours with little image fogging from light pollution. Including foreground objects, such as the castle in the image above, is a nice touch.

STAR TRAILS ABOVE SEVERA CASTLE (Canon EF camera, 28mm lens at f/2.8, Fuji Velvia 100 film, 5-minute, tripod-mounted exposure taken in December 2003 from Rome, Italy)
/// MARCO MENIERO

Top left, THE NORTH AMERICA NEBULA (NGC 7000) (Zeiss-Sonnar 180mm lens at f/2.8, Starlight Xpress HX 516 CCD camera, equatorial mounting, nine-frame mosaic, each an Hα/GB image with exposures of 30, 15, and 15 minutes, respectively) /// SÁNDOR BRASKÓ

Top right, THE LITTLE DUMBBELL (M76) IN PERSEUS (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.1, SBIG ST-10XME CCD camera, Hα/RGB image with exposures of 410, 60, 60, and 60 minutes, respectively) /// KEN CRAWFORD

Bottom, NGC 7331 IN PEGASUS (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/6.25, SBIG ST-10XME CCD camera, RGB image through Astrodon filters, 6 hours total exposure time) /// DON GOLDMAN AND KEN CRAWFORD

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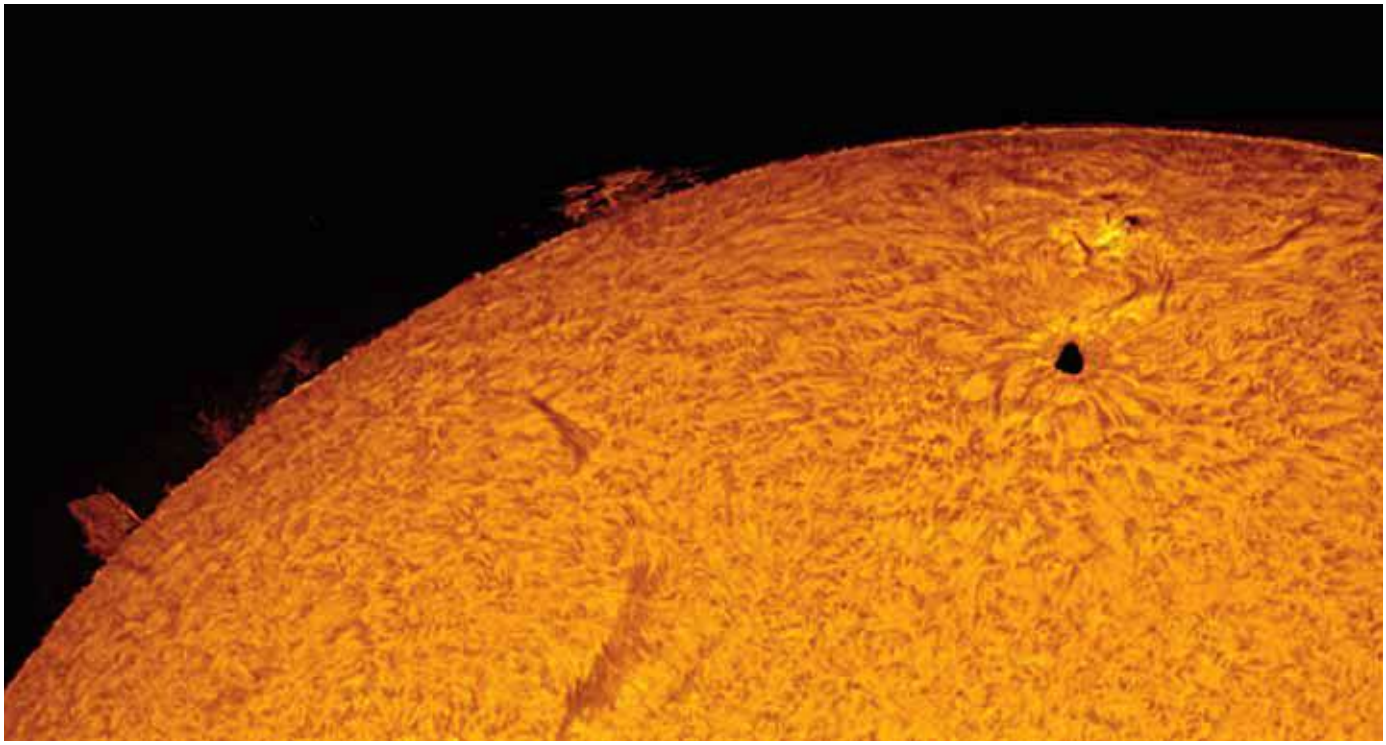
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.



Top, THE SUN IN HYDROGEN-ALPHA LIGHT (7-inch Meade apochromatic refractor, Coronado Technology Group SolarMax 90 Hα filter, Pictor 1616 XTE CCD camera, taken March 7, 2004, from Arizona Sky Village) /// JACK NEWTON

Bottom left, PLANETARY NEBULA NGC 6781 (11-inch Celestron Schmidt-Cassegrain telescope at f/10, SBIG ST-2000XM CCD camera, LRGB image with exposures of 60, 15, 15, and 21 minutes, respectively) /// DEAN SALMAN

Bottom right, GLOBULAR CLUSTER M10 (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG ST-10XME CCD camera, LRGB image with exposures of 20, 5, 5, and 10 minutes, respectively) /// MICHAEL AND MICHAEL McGUIGGAN AND ADAM BLOCK

THE MOON'S CRATER POSIDONIUS (14.5-inch Starmaster Dobsonian-mounted Newtonian reflector at f/4.3, DMK 21F04 Firewire camera, 5x Powermate Barlow lens, 1,443 frames, each a 1/128-second exposure) /// WES HIGGINS

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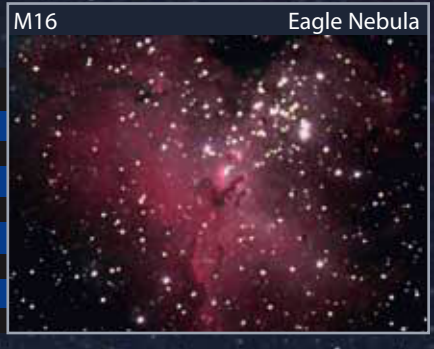
All images were taken with a Meade 8" LX200™GPS using Meade's Deep Sky Imager. Total exposure time was 10 minutes (20 exposures at 30 seconds each – automatically stacked). All images were processed using Meade's AutoStar Suite software.

M16 Eagle Nebula



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